THE

JOURNAL OF GEOLOGY

MAY–JUNE, 1897

THE LAST GREAT BALTIC GLACIER.

In a recent number of this JOURNAL[1] Dr. Keilhack criticises certain views which I have been led to entertain as to the glacial succession in northern Europe. He does not agree with me that the great terminal moraines of the Baltic Ridge are the products of a separate and independent glacial epoch. On the contrary, he and his colleagues on the Royal Prussian Geological Survey are persuaded that the moraines in question simply mark a stage in the retreat of the third ice-sheet. In the last edition of the *Great Ice Age* I have stated somewhat fully the evidence for the conclusion which my critic now disputes, and a short outline of the subject subsequently appeared in this JOURNAL[2].

Geologists who may wish to know what my views are will, I hope, take my own account of them rather than that which Dr. Keilhack has presented to his readers. Doubtless the discussion has been conducted by him in good faith and with every intention of being just, but, all the same, he has not succeeded in giving an accurate outline of the reasons which compelled me to dissent from the opinions maintained by him and his eminent colleagues. Some of the more important evidence adduced he either ignores or slurs over, while in certain other matters he has strangely misunderstood and thus unwittingly misrepresents me. Having carefully considered Dr. Keilhack's paper, I find that his criti-

[1] Vol. V, No. 2, pp. 113-125.

[2] Vol. III, p. 241.

cisms go wide of the mark; he has failed to meet my argument, and I have nothing to modify or withdraw. Under these circumstances I might well leave what I have already written on the subject, and simply appeal to it as a sufficient reply to Dr. Keilhack. Silence on my part, however, might be misunderstood, and I would not appear to be discourteous to a geologist whom I highly esteem, and whose work no one can value more than myself. At the risk of being tedious, therefore, I shall again shortly state my reasons for the faith that is in me, and take due note of my critic's objections.

It was while studying certain glacial phenomena in Britain that I was first led to inquire more fully into the grounds upon which German geologists base their belief that the terminal moraines of the Baltic Ridge were deposited during the retreat of the third ice-sheet (Polandian). The evidence which impressed me in Britain may be very shortly outlined. We have two well-recognized bowlder clays developed in the low grounds of our country—the lower of which belongs to the epoch of maximum glaciation (Saxonian), at which time the British and Scandinavian ice-sheets were coalescent. The upper bowlder clay is the ground-moraine of a less extensive, but still immense, ice-sheet, which, like its predecessor, also occupied the basin of the North Sea, so that continuous inland ice extended as before between Norway and Britain. During the formation of the lower bowlder clay the Scandinavian ice invaded East Anglia and the midlands of England, but this invasion was not repeated by the succeeding ice-sheet. Nevertheless, we have no doubt that the British and Scandinavian ice-sheets were again confluent. Along the whole eastern seaboard of Britain, from Flamborough Head to the extreme north of the Scottish mainland—a region over which the upper bowlder clay is strongly developed—all the evidence indicates that the British ice, underneath which that clay accumulated, was steadily deflected to right and left as it passed outwards into the North Sea basin. North of the Firth of Forth the trend of all the stones in the upper bowlder clay, as well as the direction of drumlins, of roches moutonnées and striæ are

towards northeast, north, and, eventually, northwest. South of the Firth, on the other hand, the direction of glaciation is southerly. In a word, it is demonstrable that *during the formation of the upper bowlder clay the British ice did not follow its natural course and flow directly outwards into the basin of the North Sea. It was deflected just in the same way as the earlier inland ice of the Saxonian stage had been.* So far, indeed, as Scotland was concerned, the ice-sheet of Polandian times was hardly less important than its predecessor.

The upper bowlder clay is the chief glacial accumulation in our lowlands, and its surface is often concealed under more or less continuous sheets of gravel and sand, while here and there it is dotted over with large erratics and traversed by eskers. All these obviously belong to the period of melting. Nowhere, however, is a vestige of terminal moraine encountered until the base of the uplands and mountains is approached. Here well-developed terminal moraines suddenly put in an appearance—the relics of large valley-glaciers and local or district ice-sheets. For a long time the general belief was that these moraines had been accumulated during the retreat of the last general ice-sheet (Polandian). Further investigation, however, proved that the outermost moraines had been laid down by advancing glaciers, which had everywhere ploughed into the upper bowlder clay, sweeping it out of the valleys, and so modifying its surface in the low grounds at the base of the mountains as to impress upon it a new configuration. The dimensions of the moraines, the extent of their fluvio-glacial gravels, and the amount of erosion experienced not only by the upper bowlder clay, but by the solid rocks themselves, all indicate that these valley-glaciers and local ice-sheets mark a distinct stage of the Glacial Period.

Again, there is evidence to show that after the retreat of the ice-sheet of the upper bowlder clay, and before the valley-glaciers in the west of Scotland had descended to the coast, the maritime districts were slightly submerged. Loch Lomond at that time formed an arm of the sea, and was tenanted by a fauna which consisted for the most part of existing British forms.

Subsequently a large valley-glacier entered the fiord, filling it up, and ploughing out preëxisting marine deposits. By this time, however, the climate had become arctic, as is proved by the character of the fauna in the contemporaneous undisturbed shelly clays of the 100-feet terraces and beaches.

Such, stated as shortly as may be, are the main facts that led me to conclude that our 100-feet beach and the contemporaneous morainic accumulations indicate a distinct stage of the Glacial Period. There was clear proof that a readvance of active glaciers had taken place after the ice-sheet of the upper bowlder clay had vanished from our low grounds, and from the lower reaches at least of our mountain valleys. But, as I remarked in my former communication to this JOURNAL, it was not quite so evident that the readvance in question had been preceded by a definite and prolonged interglacial epoch. The only evidence of preceding relatively genial conditions are the shells which the Loch Lomond glacier took up from the old sea floor and included in its moraines.

It was with these facts and inferences in view that I approached the examination of the Upper Diluvium of North Germany. Perhaps it may be objected that I had no right to expect that the glacial succession in Britain should correspond with that of the Continent, and, if we descend to details of minor importance, that is no doubt true enough. But so far as the chief stages of glacial accumulation are concerned, these must have followed in the same order throughout Europe. I do not suppose, for example, that any geologist will doubt that the epoch of maximum glaciation was one in Britain and the Continent, and the same must be true of other well-marked divisions of the glacial system. I think, therefore, that I was justified in my expectation that the Upper Diluvium of Germany would prove no exception to the rule. If the valley-moraines of the British mountains, which I formerly took to be the degenerate relics of our minor ice-sheet, mark in reality a recrudescence of glacial conditions, it was not improbable that the German Upper Diluvium would have a similar tale to tell.

Now, in the first place, the Upper Diluvium of North Germany closely resembles, in all essential particulars, the British upper bowlder clay with its associated deposits. Along the southern limits reached by the former we encounter banks and undulating hillocks and sheets of gravel and sand, just as is the case with our upper bowlder clay. Like the latter, also, the upper *Geschiebelehm* is often covered with wide stretches of water-worn materials and sprinkled with erratics. So, again, no terminal moraines present themselves as we traverse the country from south to north, until we are suddenly confronted with the great moraines of the Baltic Ridge. Here, then, we cannot but recognize a general resemblance, at least, between the glacial phenomena of Britain and North Germany. In the published works of German geologists I could meet with no evidence to show that the bowlder clay in front of the Baltic Ridge moraines was identical with the bowlder clay behind them. This identity appeared to me to have been taken for granted. At all events, no doubt had been expressed upon the subject, and no attempt made to demonstrate that the two upper bowlder clays are one and the same. Even in the paper to which I am now replying Dr. Keilhack does little more than reiterate his and his colleagues' opinions that the bowlder clays in question are contemporaneous. Apparently he thinks that their interpretation of the evidence ought to be accepted on the ground of their intimate knowledge of the glacial accumulations of their country. I need hardly say that the accuracy of their observations is not called in question. I doubt if their works have, out of Germany, gained the attention of a more admiring student than myself. Their descriptions, wherever I have been able to test them in the field, have proved, as might have been expected, full and exact. It was not without hesitation, therefore, that I found myself unable to accept their explanation of the evidence. I was consoled, however, by the reflection that they themselves are not agreed as to the precise mode of formation of the Baltic Ridge moraines. When geologists, who claim a long acquaintance with the same facts, cannot yet agree amongst themselves

as to how those facts are to be interpreted, I may be excused for forming an independent opinion. Having for many years mapped and studied glacial deposits in my own country — and such deposits are much the same in all well-glaciated lands that I have visited — I did not feel incompetent to weigh the evidence and judge for myself as to its meaning.

Dr. Keilhack does not, in my opinion, strengthen his position when he states that in numerous places the ground-moraine in front of the great terminal moraines of the Baltic Ridge passes smoothly under these. If continuous sections showing such connection are in existence, I confess I have never seen or heard of them. Possibly Dr. Keilhack only infers that the bowlder clay which he sees passing under the moraines is the same as that which overspreads the region on the other side. Be that as it may, I have not said and do not maintain that all the bowlder clay lying north of the terminal moraines is younger than the bowlder clay which occurs south of them. I am quite prepared to believe that in many places the terminal moraines have been dumped upon the bowlder clay of the Polandian stage. Further, I do not doubt that the same bowlder clay actually extends over wide areas behind the moraines, but, if such be the case, it must be largely worked up into or concealed underneath the ground-moraines and other accumulations of the great Baltic Glacier.

I now come to Dr. Keilhack's criticism of certain facts which have been adduced by me in support of the conclusion that the terminal moraines of the Baltic Ridge are deposits of a separate and independent glacial epoch.

(1) In Denmark and Schleswig-Holstein two bowlder clays have been for a long time recognized. Both of these occur over the eastern section of that region. To that region the upper bowlder clay is confined, while the latter extends westward to the shores of the North Sea. Both clays are charged with the same assemblage of erratics, the character of which shows that the ice which brought them moved out from the Baltic and traveled in a general westerly direction. In Holland

there is only one bowlder clay—that of the Saxonian stage or epoch of maximum glaciation—and it is crowded with erratics which have come from the north. The lower bowlder clay of Schleswig-Holstein and Denmark cannot, therefore, have been formed at the same time as the Dutch deposit. The latter indicates an ice flow from north to south—the former an ice flow from east to west approximately. The "lower bowlder clay" of the Cimbric peninsula is not the product of the Saxonian ice-sheet, but of its successor, the Polandian. This inference is greatly strengthened by the fact that the so-called "lower bowlder clay" of Schleswig-Holstein is underlaid by well-marked interglacial beds, which in their turn rest upon a yet older bowlder clay—in all probability belonging to the Saxonian stage. Thus we have actually three bowlder clays in the Cimbric peninsula. The uppermost and youngest of the series is confined to the eastern or Baltic side of the peninsula, and is, I believe, the product of the last great Baltic Glacier—the terminal moraines of which appear to form its outer margin. It may be added that freshwater deposits, containing relics of a characteristic interglacial flora (indicative of genial climatic conditions) have quite recently been detected in the neighborhood of Copenhagen, and thus well within the area overflowed by the Baltic Glacier. The deposits referred to are covered by the morainic accumulations of that glacier, and are underlain by diluvial gravels and bowlder clay of an earlier glacial epoch. Dr. Gunnar Andersson remarks of these interglacial beds that they have certainly been accumulated during the time that elapsed between the melting of the great Scandinavian ice-sheet and the invasion of Zealand by the last Baltic Glacier.[1]

Dr. Keilhack's remarks on the evidence cited by me and the inferences I have drawn are somewhat vague, and he ignores the occurrence of the interglacial beds and underlying bowlder-clay, which are proved to occur below the so-called "lower bowlder clay" of Holstein. He states, what is quite true, that

[1] Bihang till K. Svenska Vet.-Akad. Handlingar. Bd. 22. Afd. iii. No. 1 1896.

no single erratic can be taken as a guide to the direction in which an ice-sheet has flowed. But if by this he means that we cannot decide upon the direction of ice flow from a consideration of the general assemblage or facies of the stones in any given bowlder clay, I cannot possibly agree with him. I am well aware of the fact that every now and again erratics occur in bowlder clay, whose presence would seem to indicate a different direction of ice flow from that suggested by the others in their neighborhood. In regions which have been overflowed by ice at different times and in different directions, such occurrences must be expected. But in the case of the bowlder clays of the Cimbric peninsula it is not merely a few sporadic stones of eastern derivation that we have to deal with. The whole mass of the materials of the two bowlder clays which appear at the surface has traveled from east and northeast, So, again, the bulk of the stones in the Dutch bowlder clay have come from the north.

(2) Following De Geer, I maintain that the strong belt of terminal moraines which extends from Hango Head in a northeasterly direction through Finland, are contemporaneous with those of the Baltic Ridge. Referring to the observations of the accomplished geologists of the Geological Commission of Finland, I cite the fact that two distinct systems of glacial striæ are apparent in that country. "The striæ of the one system run in parallel directions, and extend far east and southeast of the terminal moraines. The other and younger system, on the other hand, is bounded by these moraines—the later striæ crossing the older series at various angles. When striæ belonging to both systems appear on one and the same rock-surface, the younger are always the fresher of the two, the older ones being worn and abraded. The latter, according to Rosberg, are the products of a general *mer de glace*, which attained so great a thickness that minor inequalities of the ground had little or no influence in deflecting the ice flow, which extended far beyond the limits of the terminal moraines. The ice, underneath which the younger system of striæ came into existence,

must have been relatively thin, in consequence of which the inequalities of the ground produced endless local divergences from the general direction of ice flow."[1] The small sketch map of the great Baltic Glacier given in my book is largely a reproduction of De Geer's map, published some years ago. According to Dr. Keilhack the line of union drawn from East Prussia to Finland is "purely hypothetical and supported by no observations." Here, however, he is mistaken. Let him consult De Geer's recent work, *Om Skandinaviens geografiska Utveckling efter Istiden*," and he will find that a great terminal moraine, marking the edge of the Baltic Glacier, traverses the islands of Ösel and Dagö in a north-south direction, and can even be traced for some distance on the bed of the sea. This can hardly be other than a continuation of the terminal moraines (Salpausselkä) at Hango Head.

Dr. Keilhack says he looks "for the easterly continuation of the Baltic terminal moraine much further south, in the interior of Russia." Well, it is never safe to prophesy, but I shall be surprised if his anticipations prove correct. That much gravel and sand and many erratics will be met with in the regions he refers to I can well believe, but all these, I think, will be found to be similar in character and age to the diluvial gravels, etc., which overspread the bowlder clay in the lands to the south of the Baltic Ridge. According to Dr. Vogt, of Christiania, with whom Dr. Keilhack agrees, "the Finnish terminal moraine belongs with that of middle Sweden and Norway." On the other hand, De Geer shows that the terminal moraines which occur in Norway, somewhat south of Lake Mjösen, represent the front of the Baltic Glacier during a stage in its retreat. He traces the position occupied by the ice edge right across Sweden in an easterly and northeasterly direction. The glacier is represented as filling the upper section of the Baltic basin and reaching as far south only as Åland. The great gravel-ridge at Hämeenkanga, in the middle of western Finland, would appear to be its terminal moraine in that country. This moraine occurs

[1] Great Ice Age, 3d edit., p. 474.

about 125 miles north of the older belt that extends from Hango Head to the north of lake Ladoga.

(3) Dr. Keilhack's third criticism has already been met by the remarks I have made on the subject of the upper bowlder clay of Britain. My worthy critic could not have read my work with attention or he would hardly have attributed to me the strange statement that my belief in the confluence of Scandinavian and British ice-sheets, during the formation of our upper bowlder clay, was suggested by and based on the occurrence in that deposit of Scandinavian erratics! He says: "It seems to me unnecessary entirely to repudiate the opinion of the north German geologists in order to explain the occurrence of Scandinavian bowlders in the upper bowlder clay of Britain." I have nowhere said that Scandinavian bowlders occur in our upper bowlder clay. So far as I am aware such erratics are confined to the lower bowlder clay of East Anglia and the midlands of England. Not one has been met with in any bowlder clay of East Britain north of Flamborough Head. The evidence which shows that our upper bowlder clay was formed at a time when "inland ice" filled up the basin of the North Sea, and the Scandinavian and British ice-sheets were confluent, has nothing whatever to do with the occurrence in our country of Scandinavian erratics. The great extension of ice which characterized the formation of our upper bowlder clay is demonstrated, as I have shown above, in quite another way. When Dr. Keilhack has duly weighed our evidence he will no longer consider "whether the connection of the Scandinavian with the Scottish ice in the third glacial period is more than imaginary." The fact of that connection is as well established as one can expect it to be.

(4) Believing as I do that the terminal moraines of the Baltic Ridge are the products of a distinct glacial epoch, I naturally hold that the superficial or youngest morainic accumulations which lie behind those moraines are of later age than the ice-sheet of Polandian times. Thus, I maintain that the upper bowlder clay throughout the region extending from the

Baltic Ridge to the shores of the Baltic Sea, is a younger deposit than the bowlder clay that stretches south from the Baltic Ridge to the valley of the Elbe. Further, I hold that the youngest interglacial beds, which occur between the upper and lower bowlder clays of the Baltic coast lands, are necessarily of later date than the interglacial beds which are met with in the regions lying to the south of the Baltic Ridge. Dr. Keilhack remarks that this is a "false conclusion," by which I suppose he means merely that he does not agree with me. It will be time enough, however, to call my conclusions false when he has succeeded in proving that the upper and lower bowlder clays of the Baltic coast lands are of the same age as the upper and lower bowlder clays of the Elbe valley. At present he merely assumes that they are, and expects me to accept his dictum in lieu of direct evidence or reasonable argument.

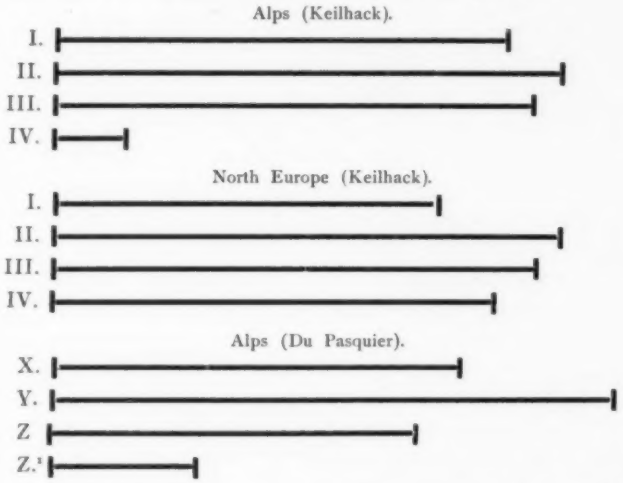
Dr. Keilhack further remarks that if I am right in my view that the terminal moraine of the Baltic Ridge defines the southern limits of a distinct glaciation, he cannot understand why each of the other terminal moraines occurring to the north of it may not also represent the edge of the ice during a distinct glacial epoch. "On this basis," he says, "the so-called 'last glacial epoch' would have to be divided into four if not five epochs, so that even the most fanatical advocate for as many glacial periods as possible would be terrified." I am sorry if Dr. Keilhack cannot distinguish any difference between the position and character of the very pronounced terminal moraine of the Baltic Ridge and the distribution and character of the minor moraines of retreat which lie behind it. For myself I have no more difficulty in distinguishing between the two sets of moraines than I have in the case of the morainic ridges of the inner zone of the Alpine *paysage morainique*. In Britain, just as in the Alpine Vorland and in north Germany, the large moraines of our district- and valley-glaciers are succeeded by numerous smaller moraines of retreat. In North America, also, geologists find no difficulty in differentiating between the first zone of great moraines of the Wisconsin formation, which mark the edge of a sep-

arate ice-sheet, and the moraines of retreat that occur behind them.

The southern limits of the Polandian ice-sheet in Britain and Germany alike is bordered by more or less thick banks and sheets of morainic gravels. These are the only terminal moraines connected with the ground-moraine of that ice-sheet. Although the surface of that ground-moraine is often abundantly strewn with fluvio-glacial detritus it shows no lines of terminal moraines comparable to those of the Baltic Ridge in Germany and of the valley-glaciers and local ice-sheets in Britain. The latter bear witness to vigorous glacial action—they have not merely been dumped upon the ground, for the local ice-flow has in many places ploughed into and pushed up preëxisting bowlder clay and ground out hollows in the solid rocks. The terminal moraines of the Baltic Ridge no doubt consist largely of water-worn materials, just as is the case with the moraines of all sheet-like or Piedmont glaciers, and much of the material has been dumped. But they also yield evidence of glacial push, for ground-moraine, confusedly commingled with gravel and sand, not infrequently enters into their composition. The lines of moraines and the irregular mounds, banks, and sheets of water-worn materials which are distributed over the ground between the Baltic Ridge and the shores of the Baltic Sea are simply moraines of retreat and fluvio-glacial deposits, and I hope no "fanatical" glacialist will "terrify" either himself or Dr. Keilhack by suggesting that they indicate "four if not five" separate glacial epochs.

(5) Dr. Keilhack further objects to my conclusion that the terminal moraines of the Baltic Ridge mark the limits of an independent glaciation, because he thinks these moraines cannot be correlated, as I have supposed, with the Alpine valley-moraines belonging to Professor Penck's "first postglacial stage." The Baltic Glacier of my fourth glacial epoch (Mecklenburgian), according to him was of such immense size and so little inferior to the ice-sheets of earlier stages that such correlation as I have attempted is almost impossible. And he gives a graphic repre-

sentation to show the "unnaturalness" of my classification. Such graphic representations, however, unless they are constructed on sound principles, are apt to express rather the views of the draughtsman than the actual facts of nature. Dr. Keilhack's diagrams are, in my opinion, constructed on a wrong principle, and were I to draw similar diagrams they would show a different result. But as my critic would probably be no more satisfied with my graphic representation than I am with his, I prefer to give one constructed a year or two ago by an independent authority — Dr. Du Pasquier, whose recent untimely death every student of glacial geology must deplore. For purposes of comparison Dr. Keilhack's diagrams are also given.



The first thing that strikes one in comparing Dr. Keilhack's representation of the Alpine glacial system with that given by the eminent Swiss geologist is the discrepancy between the lines representing the last three glacial stages (II,III, and IV of Keilhack; Y, Z, Z^1, of Du Pasquier). Dr. Keilhack obtained his lines by simply measuring the length of individual glaciers on the north side of the central Alps, but Du Pasquier has followed a differ-

ent plan. He says: "La longueur des lignes représentant les glaciations successives est proportionelle aux aires glaciées. Le rapport des aires glaciées aux différentes époques X, Y, Z, Z^1, est presque identique dans le Nord de l'Europe et dans les Alpes, et paraît devoir être exprimé par: 0,7 (?) : 1 : 0,66 : 0,27 en moyenne."[1]

If Dr. Keilhack, instead of estimating the extent of the several ice-sheets of northern Europe by drawing lines from the north end of the Gulf of Bothnia into Germany, will contrast the superficial areas of the successive glaciations he will probably come nearer the truth. He will, at all events, ascertain that De Geer's great Baltic Glacier (Mecklenburgian) large though it was, yet covered a much smaller area than that occupied by the preceding Polandian ice-sheet. Nothing could be more absurd than to describe the last great Baltic Glacier as being "little inferior to those of earlier epochs." It was very much inferior, and quite comparable, as Du Pasquier has said, with the Alpine valley-glaciers which are represented in his diagram by the line Z^1.

In correlating the Alpine valley-moraines of Professor Penck's "first postglacial stage" with the terminal moraines of the great Baltic Glacier I was well aware that no interglacial beds had been observed underlying the former. I knew quite well that the valley-moraines in question were generally considered to mark pauses in the retreat of the great glaciers of the inner zone. Latterly, however, Du Pasquier had begun to doubt if such were really the case. Quite recently he had detected evidence to show that the formation of the moraines of the "first postglacial stage" had been preceded by an interglacial interval of fluviatile or lacustrine accumulation. As Du Pasquier's observations are the first of the kind recorded, I shall quote what he says on the subject:

> Au-dessus de l'étage glaciaire Z (see his diagram) encore deux ou trois systèmes de moraines au moins, se terminant vers l'aval en nappes d'alluvions précèdent les moraines actuelles. Ces systèmes, très clairement marqués

[1] See Bulletin de la Soc. Neuchat. de Geogr., VIII (1894–5).

dans les Alpes, se retrouvent en Ecosse; ils ne paraissant pas avoir encore été suffisamment étudiés ailleurs. Ces moraines terminales, échelonnées le long des vallées, marquent-elles simplement, comme on l'admet d'ordinaire, des moments d'arrêt dans la retraite générale des glaces? Il nous paraît bien douteux qu'il ne s'agisse que de cela. D'abord, comme nous l'avons dit en traitant des glaciers actuels, les moraines terminales ne se produisent guère que pendant l'arrêt qui sépare une phase de crue d'une phase de décrue consécutive. D'autre part, dans notre Jura en particulier, certaines localités nous présentent, entre les moraines Z et d'autres subséquentes soit Z^1, des dépôts fluviaux ou lacustres assez considérables qui font penser que le drainage glaciaire avait fait place à un drainage fluvial. Ces moraines jurassiennes Z^1, nous paraissent être équivalentes à certaines moraines alpines qui forment un ensemble bien caractérisé et qui seraient elles-mêmes équivalentes aux moraines dites baltiques de l'Europe septentrionale. Nous pensons donc plutôt que ces moraines Z^1, marquent une époque glaciaire distincte, sans préjuger en aucune façon de la valeur de l'intervalle interglaciaire qui les sépare de l'époque Z et qui dut, à en juger par l'importance relative des phénomènes d'altération, être bien plus court que les précédents.[1]

I have now I think taken note of all Dr. Keilhack's remarks and criticisms which seem to call for any reply.

JAMES GEIKIE.

[1] Loc. cit.

THE POST-PLEISTOCENE ELEVATION OF THE INYO RANGE, AND THE LAKE BEDS OF WAUCOBI EMBAYMENT, INYO COUNTY, CALIFORNIA.

THE following notes are the result of observations made in the summers of 1894 and 1896. My routes were: first, from Alvord Station on the Carson and Colorado Railroad eastward on the Saline Valley road, passing through Waucobi Canyon and over the divide seventeen miles E. S. E. of Alvord; second, from Alvord through Soldier Canyon, over the range to Deep Spring Valley.

As seen from the foothills of the Sierra Nevada, looking across Owens Valley, the axis of the low portion of the Inyo-White Mountain Range, between Soldier Canyon and the ridge south of Waucobi Canyon, arches strongly to the eastward, and forms a broad embayment between Soldier Canyon on the north and the head of Waucobi Canyon on the south. (Fig. 1.) The range from east of the divide at the head of Owens Valley to Owens Lake is practically one, but unfortunately it has been given the name of White Mountain to the north and of Inyo Range[1] to the south of the embayment. Inyo is here used to include the range south of Soldier Canyon. For the broad embayment formed I use the name Waucobi, and for the ancient lake in which the lake beds were deposited the name Waucobi is also adopted. It was the examination of the lake beds deposited in Waucobi embayment that led me to conclude, from their position, that a marked orographic movement had taken place in the Inyo Range since Pleistocene time.

In crossing Owens Valley, from Alvord Station eastward, the lake beds are met with about a mile and a half east of the station, at an elevation of 100 feet above the railroad track. (*a*, Fig. 2.) They extend north of this point along the western

[1] Am. Jour. Sci., March 1895, 3d series, Vol. XLIX, p. 169.

foot of the White Mountain Range for fifteen miles or more. Near Black Canyon they occur well up the slopes, and traces of them were seen north of a line passing through Bishop Station; to the south they appear for a short distance beyond the entrance to Waucobi Canyon. As seen from Alvord Station, the

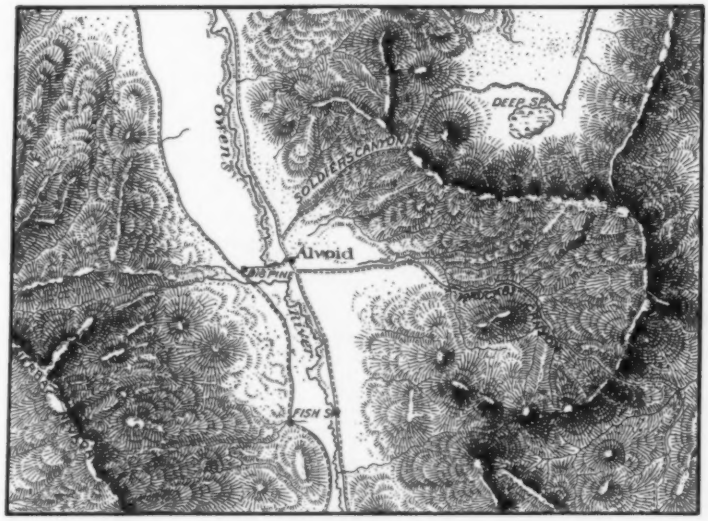


FIG. 1. Map showing the general relations of Soldier and Waucobi Canyons to Owens Valley and the Inyo Range. (Taken from Lieutenant Wheeler's map.)

beds extend from the south side of Waucobi Canyon north across the broad embayment to Soldier Canyon, and westward from three to ten miles, rising with the slope to the foot of the encircling ridge of Cambrian quartzites. (*b*, Fig. 2.) The beds at the Devils Gate in Waucobi Canyon are 2250 feet above the lowest bed exposed east of Alvord, and appear to be the same as those at the lower level; they extend on up the canyon to a level 3100 feet above the valley bottom at Alvord Station and within about three miles of the summit (below *c*, Fig. 2) at the head of the canyon.

The strata of the lake beds section three miles up the canyon are largely a fine calcareous deposit, with more or less arenaceous and argillaceous matter in the form of fine sand. Some of the white beds are made up almost entirely of the remains of fresh-water shells of the following genera, as identified by Dr. W. H. Dall: Valvata, Planorbis, Pisidium ?, and possibly Amnicola and Pampholyx. The species are undetermined, but resemble *Val-*

FIG. 2. View of Waucobi embayment from the foothills of the Sierra Nevada. *a* Lake beds at the level of Owen's Valley; *b*, contact of lake beds with the Cambrian quartzites; *c*, point above the highest exposure of the lake beds in Waucobi Canyon; *d*, point of Inyo Range overlooking Deep Spring Valley on the east; *e*, Waucobi Mountain south of Waucobi Canyon.

vata sincera Say and *Planorbis parvus* Gld. "Any of them might be recent or Pliocene; my impression from the mass is that they are Pleistocene."

As the beds approach the steeper slope of the mountain, about ten miles above the mouth of Waucobi Canyon, the sediments become coarser and coarser, and brown arenaceous beds predominate over the drab and light gray sediments. Near the contact with the quartzites, a little below Devils Gate, bowlders of the quartzite a foot or more in diameter occur in the coarse sediments, and the contact of the lake beds and the Cambrian quartzites is finely shown on the south side of the canyon.

At a point about two miles above Devils Gate, and 3000 feet above the lowest lake bed observed in Owens Valley, there is a

fine exposure on the south side of the Saline Valley road, which is the highest seen in the canyon that might be referred without doubt to the lake beds. The band exposed is about six feet in thickness, formed of layers of white, very finely granular sediment, which crumbles under strong pressure. It is capped by

FIG. 3. Lake beds, Waucobi Canyon, Inyo Range. About five miles above Owens Valley. The dark Cambrian rocks of the White Mountain Range north of Soldier Canyon are shown on the left upper half of the plate.

layers of fine conglomerate formed of small angular fragments of quartzite.

The greatest thickness of the beds observed at any one point was estimated at 150 feet. The finer, light colored calcareous beds vary from sixty to seventy-five feet in thickness. Near the valley the average dip is 3° to 5°. About two miles up it increases to 10° for a short distance and then changes to from

3° to 5° in its continuation up the canyon. The rise of the canyon bottom is nearly coincident with that of the lake beds.

The upper surface of the lake beds throughout the Waucobi embayment is covered by a layer of débris formed of fragments of arenaceous limestone, siliceous shale, and quartzite that have been brought down from the mountain slopes. Numerous washes and canyons have cut through this mantle of drift and more or less into the lake beds beneath. The general character of the deposit is well shown in the accompanying figure (Fig. 3).

The lake beds are of essentially the same character as those described by Mr. G. K. Gilbert as occurring in the Lake Bonneville basin, and by Professor I. C. Russell as occurring in the Lake Lahontan basin.[1] They were evidently deposited in the bottom of a lake, into which, near the shore line, coarse material was washed from the mountains, the finer sand and silt being carried farther out and deposited with the calcareous sediment and remains of fresh-water shells.

There may be no *a priori* reason why such deposits should not have been made upon a lake bottom sloping from 3° to 5°, but this is improbable, and it would presuppose the existence of a lake 3000 feet in depth over the site of the present Owens Valley. If such a lake existed, there must have been a barrier to the south of Owens Lake, of which no trace now remains. This is not at all probable. South of Owens Lake the divide is about 220 feet above the lake.[2] There is no appearance, as viewed from the south end of the Inyo Range, of the remains of a great barrier between Owens Lake and the drainage basin to the south.

A second conception is that the Inyo Range has been elevated, the range and the country to the eastward rising and tilting the lake beds toward Owens Valley and the Sierra Nevada.

The accompanying diagrammatic sketch (Fig. 4) illustrates the relations of the Sierra Nevada, Owens Valley, the Inyo Range, and the lake beds resting on the westward slope of the Waucobi embayment.

[1] Mon. U. S. Geol. Survey, Vols. I and XI.

[2] Owens Lake, 3567 feet above sea level; Hawai meadows, 3782 feet at divide. Wheeler).

The view of the lake beds taken from the foothills of the Sierra Nevada, looking eastward across Owens Valley, shows the lake beds at *a*, Fig. 2, at the level of the valley, and various outcrops from point to point toward the foot of the mountain at *b*.

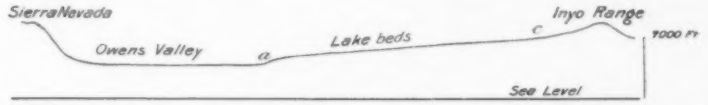


FIG. 4. Diagrammatic outline section from the Sierra Nevada to the summit of the Inyo Range, a little north of Waucobi Canyon.

The lake beds continue up Waucobi Canyon to a point approximately beneath the letter *c*, where, as previously stated, they are 3000 feet higher than the lowest beds at *a*.

The view includes the greater part of the Waucobi embayment, but does not extend on the north (left) as far as Soldier Canyon. The high point at *d* forms the summit of the ridge east of the Waucobi embayment and overlooks Deep Spring Valley to the northeastward. This part of the range, from *d* to the head of the Waucobi Canyon above *c*, forms the eastern portion of the block which appears to have been tilted toward the base of the range at *a*. On the northeastern side the slope of the range extends down to the level of Deep Spring Valley. It was on the southeastern side of this valley that I found evidence of a comparatively recent fault which is of great interest in connection with the view that the Inyo Range has been raised to the eastward and tilted to the westward within comparatively recent times. The best locality at which to examine the fault line is on the southern side of the valley, at a point about seventeen miles north of the head of Waucobi Canyon. Here there is evidence that the bottom of the valley is sinking in relation to the mountains on the southeastern side. This is shown by the presence of a comparatively recent fault scarp at the foot of the ridge and the truncating of the spurs along the base of the ridge where the fault scarp is not otherwise defined. Great springs flow out along the line of the fault, and Mr. Lewis Payson informed me that he had been unable to find bottom, by any

means at his command, in the large pools into which the springs flow, and that where wagons formerly crossed, at the southeastern end of the flat surrounding the springs, animals are frequently mired in the soft mud of the flat. The fault cuts through the Pleistocene, leaving a northward-facing wall from twenty to thirty feet in height overlooking the pools and bogs. A distant view of the ridge on the southeastern side of the valley is shown in Fig. 5. The fault scarp mentioned is directly beneath *a*, and the extension of the fault crosses the ridge a little to the right of *a*.

The eastern slopes of the Inyo Range ten miles south of Waucobi Canyon, and south of the road which passes east from the divide to Saline Valley, are very steep and join the bottom of Saline Valley as abruptly as the ridge on the southeastern side of Deep Spring Valley meets the level valley bottom. (Fig. 5.) Until a good topographic map of this region is made, it will be impossible to trace and connect the relations of the various faults and evidences of comparatively recent disturbance; but I think that there is sufficient evidence in the sinking of the southern margin of Deep Spring Valley, in the phenomena observed to the south in Saline Valley, and in the position of the Waucobi lake beds, to sustain fairly well the view that the range has been elevated to the eastward and tilted to the westward.

The total amount of the uplift cannot be accurately determined, as there was undoubtedly a slope at the bottom of Waucobi Lake from its margin toward the present site of Owens Valley. It was probably not much greater than, if as great as, the elevation of the present divide south of Owens Lake, which is about 220 feet. It is to be borne in mind, however, that perhaps in the tilting of the range the western edge under Owens Valley has been depressed, and that the valley has been silted up by the wash brought down by the river and from the adjoining mountains, quite as rapidly as, if not more rapidly than, the tilting of the Inyo Range has carried down the floor of the valley. If this is correct, the total elevation of the range since the lake beds were deposited may be as great as or greater than the difference in the

level of the lake beds at the margin of the valley and the highest point in Waucobi Canyon, or 3000 feet. There are so many factors that might be considered with more data, that only an approximation can now be made of the total displacement. We are justified, I think, in placing it at about 3000 feet, and

FIG. 5. View of southeastern portion of Deep Spring Valley, showing pond near spring, and the north face of the ridge that extends northeastward from the Inyo Range. *a*, Position of fault cutting through the ridge; *b*, southwestern end of the ridge where it unites with the Inyo Range.

thus recording the fact that a movement of considerable magnitude has occurred. That the movement is comparatively recent is proved by the characters of the lake beds and their contained fossils, which indicate the age of the deposits to be late Pliocene or Pleistocene.

It is interesting to note in this connection the account of the earthquake that occurred in Owens Valley in 1872. This earthquake, according to Professor J. D. Whitney,[1] originated in Owens Valley, and its occurrence was accompanied by a sinking of strips of land. Mr. G. K. Gilbert visited Owens Valley eleven years later, and in his observations on the subject he says

[1] The Owens Valley earthquake. Overland Monthly, Vol. IX, 1872, pp. 130–140 and 266–278.

that "the principal scarp produced by the earthquake follows the base of the alluvial foot slope of the Sierra Nevada, and has a maximum height of about twenty feet. Where this height is attained there is a companion fault scarp ten feet high facing in the opposite direction, so that the net displacement is about ten feet. At other points the main scarp is associated with others running nearly parallel and facing in the same direction."[1]

Professor Whitney, in his discussion of the earthquake[2] suggests that such disturbances might have their origin in the compression exercised by an enormous weight of material raised to a vertical height of two or three miles above the surrounding country.

The extent of the tilting of the Inyo Range to the south of Waucobi Canyon is not readily determinable. The eastern face of the range, toward Saline Valley, indicates the presence of a fault line, and the steepness of the slopes near the valley that the faulting is of relatively recent date. On the Owens Valley side the slopes are also steep, but at the mouths of the canyons there are great accumulations of talus that extend far out into the valley, and the monoclinal character of the range is broken by the presence of arching masses of strata of Triassic age, dipping westward.

North of the embayment, along the high, broad mass of the White Mountain Range, no evidence of recent elevation or tilting was observed in the hurried trip through Owens Valley along the western foot of the range.

In a paper now in preparation I shall describe certain types of faulting and tilting of monoclinal blocks of strata that are characteristic of the Great Basin area of Utah, Nevada, and southeastern California. The principal illustrations will be taken from faulted slabs of limestones collected in Waucobi Canyon on the western slope of the Inyo Range, and it is anticipated that they will aid in explaining the dynamics of such a movement as has evidently taken place in that portion of the Inyo Range which is described in this paper. CHARLES D. WALCOTT.

[1] Mon. U. S. Geol. Survey, Vol. I, 1890, p. 361. [2] Loc. cit., p. 276.

ITALIAN PETROLOGICAL SKETCHES.

V. SUMMARY AND CONCLUSION.

THE volcanoes which have been described in the preceding papers belong to the main Italian line which extends west of the Apennines from Tuscany to Naples, and which may be called the Bolsena-Vesuvius line. In a paper already quoted on the "Extinct Volcanoes of the Northern Apennines" de Stefani[1] calls attention to the fact that these volcanoes may be referred to two distinct types, distinguished not only by their structure, but by their eruptive rocks.

One type is that of the great strato-volcanoes, represented at Bolsena, Viterbo, Bracciano, and the Alban Hills, as well as at Rocca Monfina and Vesuvius farther south. The main structural features of these have been already noticed. Petrographically these strato-volcanoes are characterized by two features. In the first place leucitic rocks are very abundant at all of them, and form indeed their dominant and most characteristic feature. These are accompanied in most cases, not always, by non-leucitic rocks—ciminites and vulsinites, with exceptionally phonolite at Viterbo and toscanite at Bracciano. True trachytes are met with in abundance in the Vesuvian region and in small amount at Rocca Monfina, but elsewhere seem to be rare. Their second characteristic is the variety of eruptive products at each center, both among the leucitic and the non-leucitic rocks, as well as the abundance of tuffs. Though the variety be great, yet the rocks of each bear a great resemblance to those of the other centers, so much so that the whole line (including the centers of the second type) form an excellent example of a "petrographical province," and it is clear that the products of all the centers are related to each other genetically.

[1] DE STEFANI, Boll. Soc. Geol. Ital., X, 449–555, 1891.

To the northwest of Bolsena and between the line of volcanoes just noticed and the coast are the eruptive centers forming de Stefani's other type. The most noteworthy are those at Campiglia, Rocca Strada, Monte Catini, Monte Amiata, Radicofani, Tolfa, and Cerveteri. These are all of relatively small extent, and are in general higher in proportion to their breadth than the strato-volcanoes. Some of them, as Tolfa and Cerveteri, were superfusive and apparently formed by domal eruptions of a pasty magma. Monte Amiata was probably a true strato-volcano.[1] According to Lotti[2] the Campiglic mass was laccolitic in character, being covered by arching Eocene beds. It is noteworthy that dikes, which are practically unknown elsewhere, are quite numerous here.

As de Stefani points out, these smaller eruptions differ from the large volcanoes in two important petrographical particulars. First, each individual mass is made up substantially of one kind of eruptive rock, the rock type at each being practically persistent throughout the mass. This persistency of type at each is in marked contrast with the great variety of products found at each of the strato-volcanoes. In the second place these smaller eruptions seem never to have produced leucitic rocks—at least none are known with certainty to occur as their products. They are uniformly non-leucitic and trachydoleritic, and extreme in type—either acid or basic. The rocks of Campiglia, Rocca Strada, Monte Amiata, Tolfa, and Cerveteri belong to the toscanites—acid trachydolerites with over 65 per cent. of silica with or without free quartz; while those of Radicofani, and probably also those of Monte Catini, are basic in character, with SiO_2 about or below 55 per cent., and belong either to the ciminites or the basalts.

TRACHYDOLERITES.

The intermediate potash-rich rocks which are found along the Bolsena-Vesuvius line carry *basic* plagioclase-labradorite to

[1] DE STEFANI, Boll. Com. Geol. Ital., 1888, 223.

[2] LOTTI, cf. DALMER, Neu. Jahrb., 1887, II, 207.

anorthite—along with orthoclase, and such rocks will be called collectively in this paper by the name of *trachydolerite*, a name proposed by Abich[1] as far back as 1841. This term seems the more appropriate since one of his type rocks is that of Monte Santa Croce at Rocca Monfina, which has the mineralogical characters of one of the subgroups with the chemical composition of another. For those intermediate effusive rocks in which the plagioclase occurring along with orthoclase is *acid*—andesine to oligoclase—the name *trachyandesite*,[2] which is in use in France, will be reserved.

Ciminite.—The rocks belonging to this group are porphyritic in structure, the phenocrysts being of augite, olivine, and sometimes feldspar, and the rather light to dark groundmass being seen under the microscope to be generally a holocrystalline paste of feldspar with augite and magnetite grains, glass base being rare. The lamprophyric habit of some of the specimens has been remarked on. The ciminites are characterized mineralogically by the presence of *alkali feldspar* and a *basic plagioclase*, *augite* and *olivine*, with accessory *magnetite* and *apatite*. Biotite and hornblende (especially the latter) are either entirely absent or only present in small amount. Chemically they are rather basic, silica varying from 54 to 57 per cent.; alumina is moderately high, as are the iron oxides; magnesia and lime quite high, respectively 3 to 6 and 5 to 9 per cent. Alkalis are low for the rocks of the region, but potash is uniformly higher than soda. These rocks do not seem to be very abundant, except at the Monti Cimini, where they apparently occur in large quantities.

In Table I are given all the reliable analyses of these Italian rocks which are known to the writer, together with those of the rocks of Radicofani. Of these No. 1 of the flow at Fontana di Fiesole, near Viterbo, may be regarded as typical. Vom Rath's analysis (No. 2) of a similar rock from the same region closely agrees with this, the chief discrepancy being found in the alkalies,

[1] ABICH, Vulk. Erscheinungen, Brunswick, 1841, 100.

[2] This term has been used in a more general sense in the preceding papers.

TABLE I.

ITALIAN CIMINITES.

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	55.44	58.67	56.32	56.76	56.42	57.95	57.73	54.83	55.00	53.63	55.23
Al_2O_3	18.60	15.07	18.17	16.79	16.81	12.52	17.85	20.17	14.38	14.17	14.06
Fe_2O_3	2.09	.....	2.23	2.07	3.26	.....	4.44	4 77	.....	1.46	5.06
FeO	4.48	8.35	6.47	6.95	6.92	5.44	3.90	3.86	9.29	8.07	4.12
MnO	.....	.....	.....	.....	0.23	1.70	.....	.....	.....	Trace	0.57
MgO	4.75	2.97	2.84	1.63	3.50	5.27	1.77	1.93	7.72	7.05	4.00
CaO	6.76	8.07	5.33	6.01	5.64	3.80	3.65	4.12	8.51	8.52	9.34
Na_2O.....	1.79	3.36	1.80	2.43	1.21	3.27	3.77	3.04	2.25	1.80	2.07
K_2O	6.63	3.50	4.18	4.67	3.07	4.78	7.65	7.38	2.52	2.03	2.43
H_2O	0.25	0.82	2.15	2.44	2.25	5.49	0.09	0.46	0.48	2.01	1.07
TiO_2	0.16	.....	.....	.....	.....	.....	.....	.....	.....	SO_3 0.62	SO_3 0.84
P_2O_5	Trace	.....	0.34	0.47	1.08	.....	Trace	.....	.....	0.93	1.33
	100.95	100.81	99.83	100.22	100.39	100.22	100.85	100.56	100.15	100.29	100.12
Sp. gr.	2.700	2.765	2.52	2.47	2.625	2.668	2.61	.....	2.808	2.79	2.683

NOTES TO TABLE I.

1. Fontana Fiesole, Viterbo, H. S. Washington anal., JOUR. GEOL., IV, 849, 1896.
2. West slope of Monte Cimino, vom Rath, Zeit. d. d. geol. Ges., XX, 304, 1868.
3. Mont' Alfina, Bolsena Region, Ricciardi anal., Klein, Neu. Jahrb. B. B., VI, 7. 1889.
4. Sassara, Bolsena Region, Ricciardi anal., Klein, *loc. cit.*, 7.
5. Monte Rado, Bolsena Region, Ricciardi anal., Klein., *loc. cit.*, 33.
6. Above Ortaccio, Campiglia, Tuscany, vom Rath, *loc. cit.*, 331.
7. L'Arso, Ischia, Fuchs, Tscher. Min. Mitth., 1872, 230.
8. Scoria, Le Cremate, Ischia, Fuchs, *loc. cit.*, 231.
9. Radicofani, vom Rath, Zeit. d. d. geol. Ges., XVII, 405, 1865.
10. Radicofani, doleritic variety, Ricciardi anal., Mercalli, *op. cit. post.*
11. Radicofani, andesitic variety, Ricciardi anal., Mercalli, *op. cit. post.*

which sum up about the same, but whose relative proportions are quite different. Ricciardi's two analyses of "olivine-bearing andesitic trachyte," Nos. 3 and 4, are quite typical, though the alkalies are rather low, as is generally the case in his analyses. These rocks evidently belong to the ciminites, as has been noted on a previous page.[1] It seems proper also to class with the ciminites the so-called augite-andesite of Monte Rado in the Bolsena region[2] on the strength of Ricciardi's analysis (No. 5), though it shows rather more iron and less alkalies than the first four. While Klein does not definitely speak of orthoclase as present, he refers the high potash either to the glass or to the presence of orthoclase or anorthoclase among the feldspar laths. No. 6 is of an "augite-porphyry" forming a dike at Campiglia, described by vom Rath, who says that "it does not agree with any rock heretofore described in petrography." It is porphyritic in structure, showing phenocrysts of orthoclase, plagioclase, augite, a little biotite and quartz, and quite abundant, generally serpentinized, olivines, which lie in a light to dark greenish gray groundmass. The rock examined was evidently much decomposed, but the analysis resembles in general those of the ciminites, though alumina is decidedly low.

Analysis No. 1 yields the following approximate composition:

[1] JOUR. GEOL., IV, 554, 1896.

[2] JOUR. GEOL., IV, 554, 1896.

Orthoclase,	39.4
Albite,	15.2
Anorthite,	22.8
Olivine,	10.2
Diopside,	8.7
Magnetite,	3.0
Accessory,	0.7
	100.0

I have also included among the ciminites, both on mineralogical and chemical grounds, the well-known "trachyte" of L'Arso on Ischia. This has long been known as an instance of the exceptional occurrence of olivine in trachyte, and has been taken by Rosenbusch[1] as the type of one subgroup of his "andesitic trachytes." Judging from an examination of a number of sections from specimens collected on the spot, plagioclase is not as abundant as in the Viterbo or Bolsena rocks. There are, however, some phenocrysts with multiple twinning lamellæ whose extinctions show them to be labradorite, Ab_1 An_1 or more basic; and a certain portion of the groundmass feldspar laths are of a similar plagioclase. Olivine, while present in my specimens, is not as abundant as at Viterbo, but a colorless diopside or augite is the prominent and abundant ferromagnesian constituent.[2] These observations agree with the analyses by Doelter of the main flow (No. 7) and of the scoria of the crater at Le Cremate (No. 8), which show less magnesia and lime and more alkali than in the typical ciminites.

Though we possess no reliable analysis of it, the so-called "biotite-trachyte" of Monte Catini in Tuscany may perhaps be regarded as closely related to the ciminites. Both orthoclase and a (basic ?) plagioclase are present and some pilite pseudomorphs after olivine are noted by Rosenbusch,[3] who also remarks upon its lamprophyric character. The rock is very remarkable for the abundance of olivine along with biotite.

[1] ROSENBUSCH, Mikr. Phys., II, 773, 1896.

[2] I could find no traces of the leucite mentioned by vom Rath.

[3] ROSENBUSCH, Neu. Jahrb., 1880, 206, and Mikr. Phys., II, 764, 1896.

Closely related to the ciminites, if not to be classed with them, are the interesting rocks of Radicofani. This is a small hill a few kilometers east of Monte Amiata. The rock has been studied microscopically by Weiss,[1] Bucca,[2] and Mercalli.[3] Two varieties are to be distinguished—a doleritic and an andesitic. The former is dark gray to black, very compact and of specific gravity 2.79 (Mercalli). Augite, olivine, and feldspar phenocrysts are visible. Microscopically they resemble the dolerites, numerous large crystals of pale augite, olivine, and plagioclase (with a few of orthoclase, according to Mercalli), lying in a groundmass composed of microlites of plagioclase, magnetite, and apatite in a dark glassy base. The olivines in this rock are generally altered to fibrous green serpentine. The andesitic variety is light gray, of a trachytic aspect and specific gravity 2.683 (Mercalli). It shows phenocrysts of olivine. In thin sections are seen phenocrysts of plagioclase, orthoclase, augite, and olivine (the last altered to a reddish substance on the borders) lying in a groundmass of abundant feldspar microlites and magnetite grains, with a rather scanty yellowish glass base. It is seen that while the first variety is mineralogically a basalt, the second is a ciminite.

Three analyses of these rocks are given in Table I. Vom Rath's (No. 9) is of a specimen of the andesitic variety and is similar to those of Ricciardi. Ricciardi's (Nos. 10 and 11) differ from each other notably only in the silica, which is quite low in the doleritic variety though still higher than in normal basalts, and in the magnesia, which is extremely high in the more basic variety. Thus while the silica percentage is about that of the ciminites, alumina is decidedly lower (about that of the toscanites), iron higher, magnesia and lime very high, and alkalies low, but still higher than in normal basalts, and with potash above soda. From these analyses it seems probable that some of Bucca's and Mercalli's plagioclase is to be referred to alkali

[1] Cf. VOM RATH, Zeit. d. d. geol. Gesell., XVII, 405, 1865.

[2] BUCCA, Boll. Com. Geol. Ital., 274, 1887.

[3] MERCALLI, Atti. Soc. Ital. Sci. Nat., XXX, 1887.

feldspar—perhaps triclinic, and also that the plagioclase must be either a basic labradorite or anorthite. These rocks may then be regarded as among the more basic members of the ciminites.

We may finally allude briefly to the fact that at Rocca Monfina so-called basalts occur as products of the last phase of activity, and that there is reason for thinking that these rocks much resemble those of Radicofani and may be regarded as basic ciminites.[1]

Vulsinite.—The rocks belonging to this group are porphyritic in structure and megascopically look much like typical trachytes. Feldspar phenocrysts are especially prominent and with them are seen smaller crystals of augite and rare tables of biotite. The groundmass is light gray and in most cases is holocrystalline, or nearly so, glass being present in only small amount in the specimens examined. The feldspars comprise *orthoclase and soda orthoclase* and a *basic plagioclase*—labradorite to anorthite—in quite large amount. The ferromagnesian minerals are typically represented by *augite* or *diopside*, though *biotite* is accessory and is very abundant in some of the basic varieties. Hornblende is lacking at all the Italian localities examined, except for the occasional presence of sporadic crystals of barkevikite. *Magnetite* is generally present, but not in large amount. Both quartz and olivine are wanting, or only present sporadically.

The chemical composition of these rocks is shown in Table II.

They are rocks of medium acidity, the silica varying from 55 to 60 per cent., or perhaps somewhat over. Alumina and iron oxides are in about the same amounts as in the trachytes, magnesia somewhat higher, lime quite high (3 to 6 per cent.), and alkalies in the most representative rocks very high, with potash largely preponderating over soda. No. 1 may be regarded as the type analysis of a specimen from Bolsena. With this the analyses of vom Rath (No. 2) and Ricciardi (No. 3) agree fairly well, the greatest difference being in the alkalies. In No. 1 these are high, with potash greatly in excess of soda, while in

[1] Jour. Geol., V, 1897.

vom Rath's their total amount is about the same but the relative quantities quite different, and in Ricciardi's they are both much lower than in No. 1, but with potash in excess. It may be remarked that these mutual differences are fairly constant elsewhere and point to differences in analytical methods rather than to differences in composition.

Another typical vulsinite was found near Vetralla in the Viterbo region, and its analysis (No. 4) closely agrees with that of the Bolsena rock. The San Magno vulsinite (No. 5) is quite similar, though the silica is a little higher and the alkalies low. In regard to the rocks from Torre Alfina and San Lorenzo (Nos. 6 and 7) I must confess to some hesitation. Klein mentions olivine as occurring in notable quantity, though both analyses show small amounts of magnesia and high silica. The analyses resemble, indeed, much more those of the acid toscanites, and it seems probable that they were not made on the specimens examined by Klein. No. 8 is by Ricciardi of a specimen from the Piano delle Macinaje at Monte Amiata sent him by Verri.[1] The analysis is essentially that of a vulsinite. This view is confirmed by the description of Artini,[2] who states that it is gray, porphyritic, and composed of large phenocrysts of sanidine, smaller but more numerous phenocrysts of plagioclase, showing a core of bytownite, a border of andesine, with augite and biotite, lying in a groundmass of feldspar, augite, and glass.

Analyses 1 and 4 yield the following approximate compositions, though the results are uncertain, owing to our ignorance of the composition of the biotite and augite:

	1	4
Orthoclase,	49.5	44.3
Albite,	21.7	27.0
Anorthite,	14.4	14.1
Diopside,	6.4	3.2
Biotite,	3.4	4.8
Accessories,	4.6	6.6
	100.0	100.0

[1] RICCIARDI speaks of it as labeled "the main mass of Monte Amiata." VERRI corrects this error later (Boll. Soc. Geol. Ital., VIII, 1889).

[2] ARTINI, Giorn. Miner., IV, 7, 1893.

TABLE II.

ITALIAN VULSINITES.

	1	2	3	4	5	6	7	8	9	10
SiO_2	58.21	59.22	57.97	57.32	60.03	63.22	63.26	59.73	55.69	55.08
Al_2O_3	19.90	18.56	17.65	19.85	17.05	16.26	16.05	16.79	19.08	17.25
Fe_2O_3	4.11	....	0.63	2.21	1.83	1.41	1.04	1.44	4.07	....
FeO	0.87	6.06	7.50	2.35	4.15	3.84	6.13	3.21	3.26	9.33
MnO	....	....	0.09	....	0.09	Trace	0.14	....	Trace	....
MgO	0.98	1.12	1.71	1.60	1.12	1.25	1.29	1.47	3.41	2.77
CaO	3.58	2.96	5.53	3.82	6.58	4.75	5.50	3.27	6.87	7.34
Na_2O	2.57	4.87	1.50	3.22	2.31	2.42	1.62	4.31	2.89	1.86
K_2O	9.18	6.66	5.31	9.15	5.12	4.18	3.18	6.09	4.41	5.32
H_2O	0.74	1.14	1.82	0.57	1.42	1.87	1.57	3.93	0.17	0.17
TiO_2	Trace	....	....	....	....	....	....	....	....	....
P_2O_5	Trace	....	0.42	....	0.42	1.07	0.51	....	....	....
	100.14	100.59	100.13	100.09	100.12	100.27	100.29	100.24	99.85	99.12
Sp. gr.	2.534	2.548	2.451	2.611	2.543	2.481	2.416		2.717	2.713

NOTES TO TABLE II.

1. Bolsena, H. S. Washington anal., JOUR. GEOL., IV, 552, 1896.
2. Bolsena, Vom Rath, Zeit. d. d. geol. Ges., XX, 291, 1868.
3. Bolsena, Ricciardi anal., Klein, Neu. Jahrb. B. B., VI, 8, 1889.
4. Vetralla, near Viterbo, H. S. Washington anal., JOUR. GEOL., IV, 849, 1896.
5. San Magno, Latera, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 10.
6. Torre Alfina, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 3.
7. San Lorenzo, Bolsena, Ricciardi anal., Klein, *loc. cit.*, 3.
8. Monte Amiata, Ricciardi, Gazz. Chim. Ital., XVIII, 1888.
9. Monte Santa Croce, Rocca Monfina, H. S. Washington anal., JOUR. GEOL., V, 252, 1897.
10. Monte Santa Croce, Vom Rath, Zeit. d. d. geol. Ges., XXV, 245, 1873.

In the last rock (9 and 10) we have an example of the mutual exclusion of biotite and olivine in the Italian and other trachydolerites, to which attention has already been called by Rosenbusch.[1] It is mineralogically a biotite-vulsinite, in that it is free from olivine, but chemically a ciminite, the silica being low and magnesia and lime high. The explanation of this peculiarity may be looked for in the complexity of the biotite molecule. It was pointed out by Iddings[2] that, since the biotite molecule may be regarded as made up of molecules of olivine $2(Mg, Fe)\ O, SiO_2$ and feldspathoid molecules of the form $(H, K)_2\ O.\ Al_2O_3.\ 2\ SiO_2$, under conditions where the complex biotite molecule would be unstable it would dissociate, resulting in the formation of crystals of olivine and of a potash-alumina silicate, either leucite or orthoclase, according to circumstances. This explanation has also been adopted by Bäckström[3] in the case of the leucite-basanites of Volcanello, he considering them to be the effusive forms of magmas which would appear intrusively as minettes or kersantites. The same idea has lately been alluded to by Pirsson,[4] who adds: "This process would of course find its most natural expression in magmas rich in magnesia and potash," which, it will be observed, is the character of the ciminite magma.

[1] ROSENBUSCH, Mikr. Phys., II, 773, 1896.
[2] IDDINGS, Origin Igneous Rocks, Bull. Phil. Soc. Washington, XII, 166, 172, 1892.
[3] BÄCKSTRÖM, Geol. Fören. Stockh. Förh., XVIII, 155, 1896.
[4] PIRSSON, JOUR. GEOL., IV, 687, 1896.

Applying this idea to the rocks at hand it is evident that we may regard the olivine-bearing ciminites as formed from rather basic trachydoleritic magmas, rich in magnesia, which under other conditions of solidification would have assumed the form of biotite-vulsinites—thus adding another to the number of cases of magmas of the same chemical composition forming on solidification different mineral aggregrates. In this connection and as favoring this view of the dissociation of the biotite molecule may be mentioned the great paucity in biotite of all the leucitic rocks of Italy, and, it may be added, of the purely orthoclase-trachytes of Ischia. There seems to be, indeed, as demanded by the theory, a mutual exclusion of biotite and leucite. Olivine, it is true, is not very abundant in the leucitic rocks, except at Vesuvius, the magnesia generally entering into the pyroxene molecules, perhaps owing to the richness of the magma in CaO.

Toscanite.—The rocks belonging to this group are highly porphyritic and a glassy groundmass is often met with, though holocrystalline forms occur. They are characterized by the presence, along with the *alkali feldspar*, of a *plagioclase* which is rather more acid than in the preceding groups, generally varying from andesine to labradorite, though anorthite is found at Monte Amiata and elsewhere. The most constant and prominent ferromagnesian mineral is *biotite*, which is never wholly wanting, and at some localities, as at Campiglia and Rocca Strada, is the only colored constituent. In other places (Bracciano, Cerveteri, and Tolfa) *augite* or *diopside* is abundant along with the biotite; while again, as at Monte Amiata, *hypersthene* replaces augite as companion to the biotite. *Quartz* is often present, either in well-shaped crystals or as anhedra, but olivine is never found. *Magnetite* is rare or absent. Silica is much higher than in the other groups, varying from 65 to 73 per cent., alumina and iron are low, magnesia and lime high considering the acidity, and the alkalies also high, with potash higher than soda. We may then regard the toscanites as acid *biotite-trachydolerites*, and the rocks of Bracciano, Cerveteri, and Tolfa would

be *augite-toscanites*, while those of Monte Amiata would be *hypersthene-toscanite*, if such a subdivision be deemed advisable.

In Table III are given the best analyses of the representative Italian toscanites. Those from Bracciano, Cerveteri, and Tolfa (Nos. 1, 2, 3, 4, and 5) have been already described. Attention need only be called to the richness of the San Vito rock in Na_2O relative to K_2O, as shown by Dr. Röhrig's analysis, and confirmed by mine made later. In this respect it is notable among the rocks analyzed by me. The rocks of Monte Amiata, whose composition is given in No. 5, have been so fully described by J. F. Williams, that the reader is referred to his paper.[1] The rocks of Campiglia and Rocca Strada, Nos. 7, 8, 9, and 10, are purely biotite-toscanites and are all quartz-bearing. It will be observed that the pyroxene-bearing toscanites (1–6) are notably less acid than those which carry only biotite.

Trachydolerites elsewhere.—Having thus reviewed the main feature of the trachydolerites along the Bolsena-Vesuvius line, it will be of interest to see if such rocks are found elsewhere. Their geographically nearest counterparts are found in the Lipari Islands where vulsinites and ciminites occur according to the descriptions of Sabatini[2] and Mercalli.[3] It must be noted, however, that these are not very abundant and are associated with true rhyolites, andesites, and basalts, and not with leucitic rocks. Some of the rocks of Monte Ferru in Sardinia and of the Ponza Islands may also belong to this group, though there is doubt as to the character of the plagioclase, and they may be rather trachyandesites. Another example of such transition rocks is found at the Azores, where Hartung[4] in 1860 noted the presence of rocks intermediate between the trachytes and the basalts, which he called by Abich's name of trachydolerite. The later investigations of Mügge[5] have established the presence of such rocks, though we are again left in doubt as to the char-

[1] J. F. Williams, Neu. Jahrb. B. B., V, 403 ff., 1887.
[2] Cortesee Sabatini, Isole Eolie, Rome, 1892.
[3] Mercalli, Giorn. Min., III, 97, 1892.
[4] Hartung, Die Azoren, Leipzig, 1860, 291, 319.
[5] Mügge, Neu. Jahrb., 1883, II, 201.

TABLE III.

ITALIAN TOSCANITES.

	1	2	3	4	5	6	7	8	9	10[1]
SiO_2	64.57	64.04	66.24	65.19	67.61	65.05	70.64	69.90	71.14	73.00
Al_2O_3	16.80	14.48	15.64	16.04	14.04	16.22	14.11	14.73	11.14	14.45
Fe_2O_3	0.97	1.73	1.16	1.16	....	1.01	....	....	....	....
FeO	3.02	4.35	2.19	2.48	5.40	2.48	2.86	2.90	2.73	3.12
MnO	Trace	....	....	....	....	Trace	....	....	Trace	Trace
MgO	1.69	1.03	0.89	0.99	0.65	1.46	0.72	0.72	1.62	0.82
CaO	3.53	4.00	2.17	2.92	3.71	3.19	2.02	1.91	3.17	3.30
Na_2O	3.81	4.14	2.05	2.26	5.50	2.62	4.67	4.30	1.40	1.70
K_2O	4.01	3.65	6.60	6.11	2.41	5.52	2.95	3.01	4.13	3.18
H_2O	1.28	2.06	3.25	1.85	2.28	1.60	2.30	2.10	1.77	0.70
TiO_2	....	0.28	....	....	....	0.44	....	....	0.00	Trace
P_2O_5	....	....	....	....	....	Trace	....	....	Trace	Trace
SO_3	....	....	....	....	....	0.11	....	....	1.78	Trace
Cl	....	....	....	....	....	0.04	....	....	Trace	Trace
X	....	....	....	....	....	0.59	....	....	1.05	Trace
Sp. gr.	99.68 2.542	99.76 2.542	99.00 2.455	100.33 2.509	101.60 2.537	100.33	100.27 2.478	99.57	99.83 2.480	100.27 2.76

[1] Contains also traces of Li_2O, B_2O_3, and CO_2.

NOTES TO TABLE III.

1. Monte San Vito, Bracciano, H. S. Washington anal.
2. Monte San Vito, Bracciano, A. Röhrig anal., JOUR. GEOL., V, 49, 1897.
3. Monte Cucco, Cerveteri, H. S. Washington anal., JOUR. GEOL., V, 49, 1897.
4. Castle Hill, Tolfa, H. S. Washington anal., JOUR. GEOL., V, 49, 1897.
5. Tolfa, vom Rath., Zeit. d. d. geol. Ges., XVIII, 596, 1866.
6. Monte Amiata, mean of 7 analyses, J. F. Williams, Neu. Jahrb. B. B., V. 446, 1887.
7. Campiglia, Tuscany, vom Rath, *loc. cit.*, 640.
8. Campiglia, Dalmer, Neu. Jahrb., 1887, II, 213.
9. Sassoforte, Rocca Strada, Matteucci, Boll. com. geol. ital., 285, 1890.
10. Torniella, Rocca Strada, Matteucci, Boll. soc. geol. ital., X, 677, 1891.

acter of the plagioclase. Some of the analyses by Bunsen which Hartung gives are very similar to those of Tables I and II and indicate that it is basic. It is probable that similar rocks occur on Madeira,[1] and Renard[2] describes andesitic trachytes from Teneriffe and Ascension which may also belong here.

A group of rocks apparently resembling the Italian trachydolerites from near Buda-Pesth is described by A. Koch[3] as "labradorite-trachytes." They are composed of augite, hornblende, and biotite, and occasionally garnet, with labradorite (analyzed) as phenocrysts, and orthoclase only in the groundmass. The analyses much resemble those of the Italian trachydolerites, silica ranging from 52 to 67 per cent. and lime from 7 to 2, though magnesia is very low. Alkalies are much lower on the whole, but still higher than in normal andesites, and with potash predominating over soda.

The most interesting group, however, to compare with the Italian rocks is that of the absarokite-banakite series from the Yellowstone Park recently described by Iddings,[4] the rocks of which closely resemble those of the ciminite-toscanite series. The American rocks are similarly characterized by the presence of orthoclase and labradorite, with augite as the most prominent ferromagnesian mineral. The frequent occurrence of borders of

[1] HARTUNG, Madeira und Porto Santo, Leipzig, 1864.
[2] RENARD, Petrology of Oceanic Islands, London, 1890, 7, 23.
[3] KOCH, Zeit. d. d. geol. Gesell., XXVIII, 293, 1876.
[4] IDDINGS, JOUR. GEOL., III, 935, 1895.

orthoclase around labradorite cores is also noteworthy; a feature which we have met with so often in the Italian rocks. The most basic of them — the absarokites with silica from 47 to 52 and very high magnesia and lime — carry olivine, as do the more acid shoshonites with silica from 50 to 56; these latter correspond to the Italian ciminites. The last of the series — the banakites with silica from 51.5 to 61 — carry no olivine, and more biotite than augite, and are rather poor in ferromagnesian minerals; these would correspond to some of the vulsinites. It is especially worthy of note that in these last rocks "augite and olivine are more or less completely replaced by biotite" — the same mutual exclusion being observed here that we find in Italy. Chemically the absarokites are much more basic, while the analyses of the shoshonites and banakites closely approximate to those of the ciminites and vulsinites, except in the alkalies.

The similarity is indeed so great that the ciminites might with propriety be called shoshonites, and the vulsinites banakites. But there are certain considerations which seem to render such a course inadvisable. The difference in the alkalies has been already mentioned. While in the Italian rocks they are high and with potash very largely preponderating over soda, in the American rocks they are rather lower, and soda, while always lower in percentage, is much closer to the potash and molecularly often surpasses it. In Italy again we find the acid toscanites which are not represented at the Yellowstone Park, while at the latter we have the absarokites and nothing corresponding to them in acidity among the trachydolerites of Italy. The center of acidity, so to speak, at the Yellowstone Park seems to lie quite low, while in Italy it is much higher. Furthermore the great abundance of leucite at the Italian volcanoes is unparalleled in the American district, where the absarokite-banakites are genetically related to normal andesites and basalts, though leucite occurs to a small extent.[1] From these

[1] ROSENBUSCH, in the last edition of his Mikroscopische Physiographie (II, 1216, 1896), describes these rocks in connection with the leucite-tephrites.

facts we are led to believe that the parent magma of the Italian rocks was not only more acid than at the Yellowstone, but was preëminently a potash magma, which is certainly not true of the other. It may be added that the occurrence of two such well-marked and generally similar series of orthoclase-plagioclase rocks at widely distant localities forms a strong argument for the recognition of such types in accordance with Brögger's views.

Correlation of the trachydolerites. — Before passing on to the leucitic rocks it will be as well to examine the relationships of the trachydolerites and see what their position is in regard to other rocks of our classification. Brögger has so ably presented the arguments for the recognition of intermediate types that nothing need be added on that score, since all the arguments advanced by him for the recognition of the monzonites as an independent group of the same rank as the syenites and diorites apply with equal force to the trachydolerites and trachyandesites. The chief objection which may be brought against such ideas is that their acceptance would tend to "overburden petrological literature with new names." This is undoubtedly true to some extent, and many, perhaps most, of these names might be but temporary in their use, but they would yet fulfill their legitimate object of enabling us to comprise a given set of characters in one word, make our ideas of the various rock types more clear and precise, and thus lead us toward the solution of that vexed question — a rational and generally accepted classification of rocks, such as is found in the organic sciences.[1] The law of the survival of the fittest would hold good here as in animate nature. The needless names and types will be gradually discarded, and on what is left we may build a nomenclature of which the terms will be concordant both with each other and with the facts of nature, whenever the broad principle underlying the relationships of rocks shall have been discovered,

[1] In these, by the way, names are far more numerous than in petrology, and it may be added that it would seem that the advantage of having well-defined types would outweigh the disadvantage of putting a little greater tax on our memories.

TABLE IV.

	Trachyte Series		Trachyandesite Series		Trachydolerite Series		Andesite Series		Basalt Series	
	Alkali-feldspar rocks		Alkali-feldspar and acid plagioclase rocks		Alkali-feldspar and basic plagioclase rocks		Acid plagioclase (andesine-oligoclase) rocks		Basic plagioclase (labradorite-anorthite) rocks	
Acid	SiO_2 *ca.* 67–80	Liparite Rhyolite Quartz-Pantellerite	SiO_2 *ca.* 65–75	Iceland Liparites Vulcanite	SiO_2 *ca.* 64–75	Toscanite Dollenite?	SiO_2 *ca.* 61–70	Dacite	SiO_2 *ca.* 60–70	Santorinite
Medium	SiO_2 *ca.* 60–66	Trachyte Pantellerite	SiO_2 *ca.* 60–65	Domite Siebengebirge and Euganean Trachytes	SiO_2 *ca.* 60–64	Acid Vulsinite and Banakite	SiO_2 *ca.* 55–61	Andesite	SiO_2 *ca.* 52–60	Labradorite (of Fouqué and Michel-Lévy)
Basic	SiO_2 *ca.* 50–60	? ?	SiO_2 *ca.* 50–60	Basic Auvergne Trachytes	SiO_2 *ca.* 50–60	Vulsinite Banakite Ciminite Shoshonite Absarokite	SiO_2 *ca.* 45–55	Basic Andesite	SiO_2 *ca.* 43–52	Basalt Olivine-Basalt

as the doctrine of evolution now underlies the classifications of zoölogy and botany.

It is through considerations of this sort that I have felt justified in proposing the new names in the preceding pages, and that I sketched the following brief outline of a grouping of the feldspathic effusive rocks. In Table IV Brögger's idea is carried out, and furthermore the two main divisions of the lime-soda feldspars —the basic and the acid—are recognized. The reasons for the rehabilitation of an earlier system of classification[1] need not be gone into here, since the scheme represented is not proposed for general adoption, but only for the purpose of showing the relationship to well-established types of such rocks as those of the absarokite-banakite series and the ciminite-toscanite series.

In Table IV, then, the rocks included are classified by their dominant feldspars and by their silica content. In the first column we find the *trachytic series*, which includes only the purely or predominantly alkali feldspar rocks. These include the rhyolites (both of the potash and soda series) and the quartz-pantellerites; the trachytes proper, such as those of Ischia, Berkum, and Algersdorf, and the pantellerites; while the most basic members of this series are unknown at present, or perhaps incapable of existence, their place being taken by certain leucitites.[2] The *trachyandesitic series* would embrace those containing alkali feldspar and acid plagioclase (oligoclase-andesine) in approximately equal amounts. Their most acid representatives would include such rocks as the Icelandic rhyolites described by Bäckström[3] and the vulcanite of Hobbs;[4] those of medium acidity include what are called oligoclase-trachytes, and are typically represented by the *domite*[5] of the Auvergne and many trachytes of the Siebengebirge; while their more basic members

[1] Cf. J. Roth, Gesteinsanalysen, Berlin, 1861.

[2] They would represent chemically and mineralogically in an effusive form the basic augite-orthoclase *shonkinite* of Weed and Pirsson. (Bull. Geol. Soc., VI, 415, 1895.)

[3] Bäckström, Geol. Fören. Stockh. Förh., XIII, 637, 1891.

[4] Hobbs, Bull. Geol. Soc., V, 598, and Zeit. d. d. geol. Ges., XLV, 578, 1893.

[5] This might be used as the name for the group of medium acidity.

are found in many of the trachyandesites of the Auvergne described by von Lasaulx[1] and Fouqué.[2] Many of the rocks of the Euganean Hills also belong here. The series of *trachydolerites* has been already described. The *andesitic series* would include the dacites and andesites, with their definitions narrowed to their original limits,[3] so as to include only the rocks whose feldspars are acid plagioclase — oligoclase to andesine. In the *basaltic series*, carrying only labradorite and anorthite, we find the most acid members well represented by the "pyroxene-andesites" of Santorini, the greater part of whose feldspars have been shown by the researches of Fouqué[4] to be basic plagioclase. These have a high percentage of silica (65 to 69), and for convenience such rocks might be called *santorinites*. In the moderately acid part of the series would be found rocks corresponding to many of the labradorites of French petrographers, as well as many rocks classed as basalts, but which are more acid than the normal, such as those of the Löwenburg, Meissner, and the Vogelsberg. These may or may not carry olivine, as is also the case with the intermediate and basic trachydolerites and andesites. Toward the basic end we would have the basalts proper, chiefly anorthite-bearing and with or without olivine; while below these would come such rocks as the limburgites and augitites.

It will be seen from the above that the trachytes are rich in alkalies and poor in lime; the trachyandesites rather rich in potash and also in soda and lime; the trachydolerites rich in potash and lime, but poor in soda; the andesites rich in soda and lime, but poor in potash and the basalts very rich in lime and poor in alkalies, especially potash.

A somewhat similar table is given by Fouqué and Michel Lévy on page 155 of their Minéralogie Micrographique (Paris, 1879). The effusive rocks are divided according as they con-

[1] Von Lasaulx, Neu. Jahrb., 1870, 1871, 1872.

[2] Fouqué, Étude des Feldspaths, Paris, 1894, 254–270.

[3] Roth, Gesteinsanalysen, Berlin, 1861, p. XLV. Von Hauer und Stache, Geologie Siebenbürgens, 1863, 70, 79.

[4] Fouqué, Santorini et ses Eruptions, Paris, 1879; also Étude des Feldspaths, 317–320. The smaller groundmass microlites are more acid.

tain alkali feldspar, oligoclase, labradorite or anorthite, and these groups are subdivided according to their ferromagnesian minerals, biotite, hornblende, or pyroxene. Neither trachyandesites nor trachydolerites are mentioned.

It must also be noted that a somewhat similar scheme was proposed by H. O. Lang[1] in 1891 and carried out by him in great detail. He bases his purely chemical classification entirely on the relative proportions of the percentages of lime, soda, and potash, neglecting the other components and the mineralogical composition, so that the present grouping and his differ distinctly from each other.

LEUCITIC ROCKS.

Comparatively little can be said of these rocks here, since detailed descriptions of many of them have been already given, and since a proper treatment calls for more space than is available. As regards classification, while they are on the whole sharply separated from the trachydolerites, yet *inter se* they grade into each other to such an extent that the discrimination of definite types is more than usually difficult and subjective in character.

It will also have been evident from the descriptions given that many of the varieties described differ from the types generally accepted. Thus those rocks which have been called leucite-phonolite for want of a better name contain only a small amount of nepheline and are quite distinct from the typical German leucite-phonolites. The unfortunate difference of opinion as to the use of the terms leucite-trachyte and leucite-phonolite has been noticed, and in other ways the need is made evident of some general revision of all this group of important rocks. At present, however, the material is not at hand for such an attempt, which it is hoped will be undertaken later; and the names used are to be regarded as provisional only, and the whole group of leucitic rocks as the subject of future investigation. In Table V, only a few of the many analyses are given,

[1] H. O. LANG, Min. Petr. Mitth., XII, 199, 1891.

TABLE V.

ITALIAN LEUCITIC ROCKS.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
SiO_2..	45.93	47.89	48.89	49.03	47.82	47.40	49.73	50.24	52.16	55.11	55.87	55.85	55.10	55.17	55.21	55.26	58.48	59.51
TiO_2..	.....	0.77	.....	.....	.....	0.30	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....
Al_2O_3	18.72	18.25	16.05	15.18	18.85	19.84	19.20	20.09	15.03	16.07	21.82	19.31	19.20	20.49	19.81	16.36	19.56	18.89
Fe_2O_3	.....	4.93	1.80	2.07	5.24	2.72	5.50	2.54	3.17	3.04	2.34	3.77	.....	3.27	2.69	5.76	.....	.....
FeO ..	10.68	3.64	10.09	6.32	5.12	4.40	2.41	5.65	8.42	8.46	1.10	1.88	6.86	2.74	2.86	2.90	4.99	5.26
MnO..	.....	Trace	0.43	0.19	.....	.....	Trace	Trace	0.24	.....	Trace	Trace	.....	Trace	.....	.....	.....	Trace
MgO..	5.67	3.68	3.98	6.05	4.40	4.23	2.63[2]	3.65	4.69	3.10	0.48	1.73	1.18	1.58	1.68	1.14	0.53	1.50
CaO..	10.57	8.70	11.88	12.58	9.51	9.88	7.96	7.83	10.07	6.46	3.07	3.84	3.75	3.73	4.61	3.90	2.60	1.90
Na_2O.	1.68	2.60	1.81	1.49	2.65	2.93	1.99	2.97	2.38	1.58	4 81	3.39	2.68	2.27	3.13	4.08	3.14	4.99
K_2O..	6.83	8.23	3.00	4.07	6.41	5.91	9.39	7.45	2.47	5.07	10.49	8.77	10.78	9.58	8.45	8.82	10.47	7.25
H_2O..	0.59	0.65	1.39	2.09	.....	1.66	1.19	0.36	0.72	0.89	0.34	1.14	1.22	0.99	0.99	1.20	0.24	0.56
P_2O_5 ..	.....	.....	0.29	0.86	.....	.....	.....	.....	1.15	0.75	.....	.....	.....	.....	.....	.....	.....	.....
	100.67	99.34	100.19[1]	99.93	100.00	99.27	100.00	100.78	100.50	100.53	100.32	99.68	100.77	99.82	99.43	99.78	100.01	100.05[3]
Sp.gr.	.....	2.781	2.811	2.743	.....	.....	2.655	.....	2.749	2.546	2.557	2.648	2.501	.....	2.609	.....	2.572	2.603

[1] Also 0.59 SO_3.

[2] By difference.

[3] Also 0.19 Cl.

NOTES TO TABLE V.

1. Leucitite, Capo di Bove, Bunsen anal.
2. Leucitite, Crocicchie, Bracciano, Washington anal.
3. Leucitite, Sassi Lanciati, Bolsena, mean of 2, Ricciardi.
4. Leucite-basanite, Toscanella, Bolsena, Ricciardi.
5. Leucite lavas, Vesuvius, mean of 49 anals., Roth, Geologie, II, 268.
6. Leucite-tephrite, Rocca Monfina, Röhrig.
7. Leucite-tephrite, Bracciano, Washington.
8. Leucite-tephrite, Monte Cavallo, Bolsena, Washington.[1]
9. Leucite-tephrite, Monte Bisenzio, Bolsena, Ricciardi.
10. Leucite-tephrite, Montalto, Bolsena, Ricciardi.
11. Leucite-phonolite, Lake Bracciano, Washington.
12. Leucite-phonolite, Bagnorea, Bolsena, Washington.[1]
13. Leucite-phonolite (?) Bolsena, Vom Rath.
14. Leucite-trachyte. San Rocco, Mte. Vico, Washington.[1]
15. Leucite-trachyte, Monte Venere, Viterbo, Washington.
16. Leucite-trachyte, Madonna di Lauro, Viterbo, Röhrig.
17. Leucite-trachyte (?), Monte. S. Antonio, R. Monfina vom Rath.
18. Leucite-trachyte, Viterbo, vom Rath.

the most representative being selected. Many more must be made before these rocks can be adequately treated from a chemical standpoint.

By far the best defined type is that of the so-called *leucitites*, which are quite constant in structure and mineralogical composition, as already described. The chemical composition of typical leucitites is given in Table V, Nos. 1, 2, and 3. They are very basic rocks, with high iron and lime, quite high magnesia, and high alkalies. *Leucite-basalts* seem to be quite unknown in the Italian localities—perhaps owing to the richness of the magma in lime, which makes a basic plagioclase-free rock almost an impossibility if any of the MgO is withdrawn from a possible diopside molecule to form olivine. Outside of the Vesuvian region, where they occur in abundance, *leucite-basanites* are only met with in small amounts. Their analyses (Nos. 4 and 5) resemble those of the leucitites except that they are higher in magnesia and iron as well as in lime, and those of Bolsena low in alumina. The *leucite-tephrites* form a group which is one of the most difficult to classify satisfactorily owing to the

[1] Made since publication of their respective papers.

large number of transition forms toward the leucitites on the one hand and the leucite-trachytes on the other. In general they are characterized by a rather doleritic micro-structure and the plagioclase is basic; chemically they are very basic in character, their silica content scarcely running above 50 per cent. Leucite-tephrites of this type abound at Bolsena, Rocca Monfina, and Vesuvius, and typical analyses are represented by Nos. 6, 7, and 8. Other leucite-tephrites occur whose silica content is higher. Examples are the rocks of Montalto (No. 10), in which Klein reports the feldspar as anorthite, and that of Monte Bisenzio (No. 9). Such acid leucite-tephrites, however, have not come under my own observation, and the high silica is to be explained by the presence of considerable orthoclase. Indeed my observations and such analyses as I have been able to make lead me to think that a typical Italian leucite-tephrite (which is poor in orthoclase) has a silica percentage of 50 or less, and that the plagioclase is generally, if not normally, a basic one.

When we reach the *leucite-trachytes* and *leucite-phonolites* we find a decidedly more acid group of rocks with silica ranging from 55 to 59. These shade off into the leucite-tephrites to some extent, but on the whole are distinctly separated from them. Of leucite-trachyte we have few analyses, Nos. 14–18 being the only reliable ones known to me. They show high alumina, low magnesia and lime, and high alkalies — especially potash, though this last feature is perhaps not as marked as we might expect. The analyses of leucite-phonolite (Nos. 11, 12, 13) resemble these very closely, though soda is somewhat higher, and are quite different from those of leucite-phonolites from Germany,[1] which are much more basic and with soda much higher than potash. Indeed, so great is the resemblance to analyses of leucite-trachyte that these Italian leucite-phonolites ought properly to be called nepheline-bearing leucite-trachytes. They all carry orthoclase in large amount, especially in the groundmass, and nepheline occurs as the last product of crystallization. Only one case of a purely leucite-nepheline

[1] ZIRKEL, Lehrbuch, II, 465, 1894.

rock was observed, that at the Asteria di Biagio, near Orvieto.[1] It may be noted here that in all these leucitic rocks the dominant feldspars are orthoclase and a basic plagioclase, that augite and diopside are the prevailing ferromagnesian minerals, that both biotite and hornblende are rare, and that they are rich in potash and also in lime. They thus resemble in their broad features the non-leucitic rocks—apart from the presence of leucite.

Turning to Table V it will be observed that there is a break in the silica percentages between 50 and 55. Below the former are the leucitites, leucite-basanites, and most of the leucite-tephrites; between the two very few analyses are seen, while between 55 and 56 there is a large number of analyses, and above this last a much smaller number, with silica running up to nearly 60, which is the extreme figure for leucitic rocks. This feature is best seen when all the analyses available are tabulated. Space considerations prevent this being done here, but the break between 50 and 55 is very evident. The number of analyses represented is so large, and covers so many varieties of rock, that this clustering of the silica about 49 and 56 may be reasonably assumed to exist in fact and not to be due to chance in the selection of analyzed material, as might well be the case with few analyses. We may note also in the analyses of Table V that, while alumina is somewhat variable, it is in general higher in the basic group than in the more acid, as is also true of iron oxides Lime and magnesia show the greatest differences, there being more than double the amount of them in the basic than in the acid group. There is less difference to be observed in the alkalies, they being very high in both groups, but perhaps more so in the acid one.

Comparison of the trachydolerites and leucitic rocks.—The general similarity of the two groups has already been noticed, and it is further of great interest to observe, on referring to Tables I, II, and III, that a clustering of the analyses about definite points is to be found in the analyses of the trachydolerites as well as

[1] Jour. Geol., IV, 558, 1896.

in those of the leucitic rocks. The ciminites and vulsinites reach no higher than 60 per cent. of silica, and lie in general between 55 and 58 per cent., while the toscanites are no lower than 64 per cent., and are in general much higher. Corresponding differences may also be noted in the other constituents, especially Fe_2O_3, FeO, MgO and CaO. It is also seen that transitional chemical forms are of limited occurrence, though the analyses are not as numerous as in the leucitic group. The analyses, then, of both groups are clustered about certain points and do not form a gradual series from the most basic to the most acid, as Brögger understands a series to be constituted. A similar clustering of the analyses may be seen at such volcanic localities as the Yellowstone Park, Montana, Cape Verde Islands, and Ægina and Methana; and the study of complete series of analyses would probably reveal the same state of affairs elsewhere. Indeed the fact may be said to be generally known, though perhaps not definitely formulated. An explanation which may be suggested is that this clustering of analyses is due to a quite complete course of differentiation, assuming the correctness of the differentiation hypothesis.

Each main group of rocks, therefore, may be subdivided chemically, and mineralogically to a certain extent, into two subgroups (classing the ciminites and vulsinites together), a basic and an acid. Further, while the leucitic subgroup is more basic in each case than the corresponding trachydoleritic one, yet the variations in each are similar. These are best seen on tabulating the means of the best of the various preceding analyses. It is scarcely worth while to do so in this place, but the main features may be briefly pointed out. There is a difference in each case of 8 to 10 per cent. of silica; and iron, magnesia, lime, and to a less extent alumina, are higher in the basic group, while alkalies show less regularity. The molecular ratio of soda to potash varies in my separate analyses from .3 to 1.2, being fairly constant (.5 to .6) in the leucitic groups, and with higher soda at the extremes of the trachydolerites. It is probable that with more numerous analyses the resemblances would be even

greater since there are indications of a division of the basic leucitic subgroup into two divisions corresponding to the ciminites and vulsinites. These would include on the one hand the leucitites and leucite-basanites, and on the other the leucite-tephrites. There exist then along the Bolsena-Vesuvius line at least two well-defined series with correlated members in each, the Ciminite-Vulsinite-Toscanite Series and the Leucitite-Leucite-tephrite-Leucite-trachyte Series. These two resemble each other very closely, except for the presence of leucite in the latter and the uniformly greater basicity of the correlated members of this series as compared with those of the former. There also occurs a typically trachytic group in the Vesuvian region, while the phonolites of Viterbo mineralogically stand apart, but chemically are related to the leucite-trachytes. These series are, however, not gradual in Brögger's sense of the term,[1] but form related but separated groups of rocks.

Differentiation of the magma.—The question of the process or processes of differentiation and the composition of the parent magma is of great interest, but needs far more detailed and extensive knowledge of the regions involved and of the rocks than is yet available. The question is somewhat complicated by the presence of leucite in such large amounts, and by the fact already noted, that it is possibly derived from a potential biotite molecule, or at least that some connection seems to exist between the two minerals. It is pretty generally believed that leucite is essentially an effusive mineral, though some cases of intrusive leucitic rocks are known. Therefore, although the first impulse is to consider the leucitic rocks as distinct differentiation products from the trachydolerites, yet caution must be used, since it seems possible that their differences are due rather to differing conditions of extrusion than to differing secondary magmas. This, of course, would not be true in all cases, since leucite would be formed in a potash-rich magma poor in silica, while orthoclase would take its place in one more acid. This is seen clearly in the rocks with silica below 55 which are almost

[1] BRÖGGER, Grorudite—Tinguait Serie, Kristiania, 1895, 169.

uniformly leucitic, while those with silica above 60 are as uniformly leucite free and orthoclase bearing. It is in the intermediate group with silica from 55 to 60 that we must look for evidences of the connection of leucite with extrusive conditions. These magmas are apparently in a nicely balanced chemical condition, which needs only a comparatively slight change of conditions to throw them into the one mineralogical group or the other. It is known that the leucitic rocks are almost invariably met with as flows, while the trachydolerites more frequently take the form of domal extrusions; that the leucitic rocks are the products of later eruptions, on the whole, than the trachydolerites except at Rocca Monfina; and that they have been ejected at central vents while the trachydolerites are more generally peripheral. This is suggestive of the idea that leucite has been formed in place of orthoclase during the simmering of the magma in the throat of the volcano under low pressure,[1] while the peripheral orthoclase magmas were partially crystallized under greater pressure.

In view of the above facts and those given in the preceding section I am inclined to think that the two main groups of rocks which are found along the Bolsena-Vesuvius line do not represent two distinct primary differentiation products, but that their differences are due to diverse conditions of extrusion, solidification, and the like, these conditions being, of course, secondary to the chemical character of the differentiation products, as has just been explained.

In regard to the character of the parent magma we may feel confident that it was very rich in potash and lime,[2] basing our judgment on the preceding descriptions and analyses. More than this we cannot postulate with any degree of certainty, but its general composition is perhaps shown by the mean of

[1] Cf. BÄCKSTRÖM, op. cit., p. 163; also LACROIX, op. cit., 637 ff.

[2] The hypothesis advanced by LAVIS (Natural Science, IV, 138, 1894) that the large amount of lime is due to absorption (osmosis) from the subjacent limestone traversed by the magma must be mentioned, though the writer can only admit its influence in a most limited way, if at all. The researches of Brögger and Pirsson have shown conclusively that it does not hold good elsewhere, and various considerations, which need not be gone into here, lead me to minimize its effect in Italy also.

the extreme differentiation products—the toscanites and basic leucitic rocks—or by the mean of the ciminites, vulsinites, and acid leucitic rocks, which closely resemble each other. On such a basis we could suppose it to have approximately a composition as follows: SiO_2=57–58, Al_2O_3=17–18, total iron oxides as FeO=6–7, MgO=2–3, CaO=5–6.5, Na_2O=2–2.5, K_2O=7–8, H_2O=1–1.5 per cent.

Whether the original magma differentiated horizontally from north to south we are not yet in a position to discuss, but at each center we may suppose the body of magma to have been quite completely differentiated. We would thus have the toscanites and the basic leucitic rocks (leucitites and leucite-basanites) representing the extreme products—the oxyphyric[1] and lamprophyric types, respectively. Apart from questions of conditions of solidification, the absence of leucite in the vulsinites may be explained by their higher silica,[2] while in the ciminites and biotite-vulsinites the high magnesia conditioned the formation of olivine, leaving the remaining part of the magma sufficiently acid for the formation of orthoclase rather than leucite. That these suppositions are possible may be seen on comparing analyses 1, 4, and 9 of Table I and 1 of Table II, with 11, 12, 14, and 15 of Table V, which are practically identical except for the silica in the first two, and the magnesia in the second two of the trachydolerites.

All this is, however, admittedly speculative to a large extent, and these views are advanced in a provisional way to be tested, and perhaps greatly modified, by future investigations. Finally, it has perhaps have been noticed that little or no reference is made to the succession of the rocks. The omission is intentional, because it does not seem to the writer, even granting that the order of eruptions is of the importance often attributed to it, that our knowledge of the subject along the Bolsena-Vesuvius line is sufficient to be of much value.

HENRY S. WASHINGTON.

[1] PIRSSON, Am. Jour. Sci., L, 118, 1895.

[2] The anomalous acid leucite-tephrites observed by vom Rath and Ricciardi are against this view, and some of them need confirmation.

VARIATIONS OF GLACIERS.[1] II.[2]

THE first annual report of the *International Committee on Glaciers* has been published,[3] and gives the state of glaciers in various regions of the world so far as reports have been received, with references to some of the original sources of information. This committee was appointed to stimulate and record observations on glaciers. The following is a summary of the report.

No glaciers, except those of the Alps, have been under observations long enough to yield very definite results; but these have shown a decided periodicity of about thirty-five years in their size; it is not improbable that glaciers in other regions may have a similar periodicity.

A *period* is the time during which a glacier goes through all its changes; it begins at a *minimum*, continues through the *phase of increase*, the *maximum*, and the *phase of decrease*, and ends at the following minimum.

The Alps.—The glaciers of this chain were for the most part in the phase of decrease from 1855 to 1875; since then a number of glaciers have entered the phase of increase, namely: all those of the Mont Blanc group, about a half of those of the Valais, not more than a quarter of those of the Bernese Oberland, a few in the eastern Alps, and none east of the Brenner pass; so that the phase of increase at the end of the nineteenth century has been limited and not general; and observations from 1893 to 1895 show that many of the glaciers which have recently been advancing are again in retreat.

Of the glaciers observed in the Eastern Alps in 1895 there were about fourteen increasing, twenty decreasing, and five stationary.

[1] Read before the Geological Society of America at the Washington meeting, 1896.

[2] See this JOURNAL, Vol. III, pp. 278–288.

[3] Archives des Sciences, Vol. II, pp. 129–147, Geneva, 1896.

In the Swiss Alps where observations have been more general and have extended over a longer period, we find, in 1895, twelve glaciers increasing, forty-eight decreasing, seven stationary, and ten doubtful; in addition, several glaciers were measured for the first time in 1895, so that we may expect results from a still larger number in the future.

The great majority of the glaciers of the French Alps are decreasing in size.

The Pyrenees.—The eleven glaciers of this chain for which we have results, show five increasing, five decreasing and one stationary. Considerably over 200 French glaciers are now under observation.

The Caucasus.—A number of glaciers in this chain have been observed, showing a fairly general retreat; in 1894 some of the névé fields were growing larger.

Central Asia.—The glaciers are mostly in the Pamir, the Tian-schan, and the Alai mountains. They are of considerable size, and appear to be pretty generally in retreat.

Nova Zembla.—Glaciation is increasing.

The Scandinavian Alps.—The Norwegian glaciers do not show evidence of having participated in the great retreat of 1850–1880. The state of the vegetation in the immediate neighborhood of the glaciers shows that in many cases they have either kept or reattained the dimensions they had a century or so ago. There have been some advances and some slight recent retreats; there are no indications of any present advance.[1]

The Swedish glaciers are too little known to yield any definite results as yet.

The Himalaya.—Sir W. M. Conway reports the glaciers of this range in retreat, so far as observed, with the exception of the Bagrot glacier, which is beginning to advance.

The New Zealand Alps.—Considerable attention has of late been given the fine glaciers of this region. They seem to be either stationary or decreasing.

[1] See especially Beobachtungen üb Gletscherschwankungen in Norwegen, by E. RICHTER. Petermann's Mitth. Vol. XLII, p. 107.

United States of America.[1]—The glaciers of the United States have for the most part been so infrequently visited that the information regarding them is very meager. Professor Russell, in 1892, collected the evidence showing that in general they are retreating.[2] A few glaciers, however, give evidence of being in a state of advance.

The Malaspina glacier occupies a large plateau on the southern side of the St. Elias Mountain range. Though in general receding, a part of it near the Yahtse River was advancing and destroying trees in 1886.[3] Professor Russell states that the southeastern portion of the same glacier near Point Manby has recently advanced a distance of 500 meters and again retreated.[4]

The Frederika glacier, in the interior of Alaska (long. 142° 35′ N., lat. 61° 40′ W.) was the only glacier in its neighborhood advancing in 1891.[5]

Mr. John Muir writes me that a glacier at the southern end of the Fairweather range was advancing and destroying trees when he visited it in 1880.

Muir glacier, Alaska, which has in general been receding for the last hundred years or more, made a temporary advance between 1890 and 1892 of nearly 300 meters, but in 1894 it had again retreated to its limit of 1890. This glacier reaches tide water and ends in a vertical cliff of ice, 2.75 kilometers (9000 feet) long and 50 to 65 meters (150–215 feet) high; on each side of this cliff the glacier rests on the land and ends like an ordinary alpine glacier. The oscillation mentioned applies only

[1] This paper gives a more detailed description of the variations of the glaciers of this country than is contained in the Rep. of the Intern. Com. An excellent account of our present knowledge of these glaciers has been given by Professor Israel C. Russell in his recently published book, "The Glaciers of North America."

[2] Climatic Changes Indicated by the Glaciers of North America, by I. C. RUSSELL. Am. Geol., Vol. IX, 322–336.

[3] Shores and Alps of Alaska, by H. W. STETSON KARR, p. 77.

[4] Am. Geol., Vol. IX, 329. The best map of this region is in Russell's Second Expedition to Mt. St. Elias, 13th Ann. Rep. U. S. Geol. Sur., p. 6, or his Malaspina Glacier, this JOURNAL, Vol. I, p. 221.

[5] An Expedition to the Yukon District, by WILLARD HAYES, Nat. Geog. Mag., Washington, 1892, Vol. IV, p. 153.

to the part facing the water; the sides have been steadily receding.[1]

Mount Rainier is a volcanic cone, 4400 meters high, in the state of Washington, bearing on its steep slopes about a dozen glaciers from five to ten kilometers long. Information has reached me concerning the Carbon glacier on the northern, the Willis on the northwestern, and the Nisqually on the southern face of the mountain. All three of these glaciers are steadily receding.

Mr. Otto J. Klotz made a photographic study of the end of Baird glacier, Alaska (long. 132° 50′ N., lat. 57° 8′ W.) in 1894.[2] This will be the beginning of a careful record of the variations of this glacier.

In conclusion, the very incomplete data indicate that, with few exceptions, the glaciers of the United States are shrinking at the present time.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1896.[3]

Cook's Inlet.—A glacier on the Kenai Peninsular has receded about 250 feet between 1880 and 1895.[4] Mr. Dall writes that he thinks all the glaciers on the Pacific coast which he has personally visited are retreating.

Chilcat Pass.—The glaciers on the southern side of this pass are receding. (*J. E. Spur.*)

Glacier Bay region.—Mr. John Muir reports that he found Rendu and Carroll glaciers, at the head of the bay, from three to seven kilometers (two to four miles) shorter in 1896 than they were in 1879. Muir glacier also continues to recede.

[1] Studies of Muir Glacier, Alaska, by HARRY FIELDING REID, Nat. Geog. Mag. 1892, Vol. IV, pp. 33–42; and Glacier Bay and its Glaciers, 16th Ann. Rep. U. S. Geol Sur., pp. 440–442.

[2] This JOURNAL, 1895, Vol. III, pp. 512–518. I recommend this article to observers as an example of how much of permanent value can be done in a short time by the photographic method.

[3] A synopsis of this report will appear in the Second Annual Report of the International Committee.

[4] W. H. DALL, Bull. Am. Soc., 1896, XXXVII, 15,

Mt. Rainier.—Professor I. C. Russell writes me:

In company with Bailey Willis and George Otis Smith of the United States Geological Survey, I visited Mount Rainier, Washington, and spent two weeks, from July 15 to August 1, in examining the glaciers on its sides.

The Willis, Carbon, Winthrop, Emmons, Nisqually, and Cowlitz glaciers were visited. Each of these furnishes clear evidence of having recently been lowered by melting, especially in the lower courses. The extremities of the three first named were examined and in each case a recent and marked recession was manifest.

The extremity of Carbon glacier, as judged by Willis, has receded about 100 meters since his former visit in 1881. The extremity of the glacier at the date mentioned was a vertical precipice of nearly clear ice, but now has a slope of 55° to 60° and is débris covered.

Willis glacier is divided at its terminus by a rugged boss of rock, for which I suggest the name Division rock, the down-stream face of which is a rugged precipice by estimate 120 or 150 meters high. I am informed by Willis, who saw it from below, that in 1883 the glacier broke off not far behind the summit of this precipice and formed walls of ice descending on each side of it. The ice did not cover the highest peak on Division rock at the date mentioned, and there are about ten small spruce trees growing on the apex. These trees are certainly more than fifteen years old. The upstream side of the rock, below the trees, is strewn with stones and dirt and has evidently been recently occupied by the glacier. At the time of my visit the ice in the central part of the glacier had receded 175 meters from the edges of the precipice. Fresh lateral moraines elevated from thirty to forty meters above the level of the glacier in 1896, and extending fully three kilometers (two miles) above Division rock, agree approximately with the 1883 level of the ice as reported by Willis.

Willis glacier now divides on reaching Division rock into two sharp-pointed tongues of débris-covered ice which end with low frontal slopes The extremities of these tongues are about abreast of the summit of Division rock. Where the glacier divides a pyramidal monument of angular stones about one and one-third meters high is built. This monument records the limit of the ice at the place where it divides, on July 31, 1896.

Up stream from Division rock there is another similar eminence which might possibly be mistaken for it, if the glacier continues to recede. The rocky knob referred to is now a part of the right or northern wall of the glacier.

Eight hundred and forty meters, as measured by pacing, above the monument described above, there is an ice-fall in the glacier 130 to 135 meters high. The descent of the surface of the glacier from the base of the ice-fall

to the monument is 280 meters, by aneroid. The gradient becomes progressively steeper as one descends from the base of the ice-fall.

No marks were made to record the extent of the other glaciers visited.

Mount Hood, Oregon.—There are eight glaciers on this volcanic cone; all of them are steadily diminishing in size. The Eliot glacier on the north side of the mountain is about four kilometers (two and one-half miles) long and about 0.8 kilometer (one-half mile) wide; and shows a marked recession in the last three years. Before that the face was much steeper.[1] In the central part of the glacier near the end the velocity of movement has averaged about fifteen meters (fifty feet) a year since 1890. Coe glacier, which lies next to the Eliot on the west, is about four kilometers (two and one-half miles) long and 0.4 kilometer (one-quarter mile) wide. (*W. A. Langille.*)

Illecillewaet Glacier, Selkirk Mountains, Canada.—As there is at present no one on the committee representing the British colonies, I give what information I have concerning this glacier.[2]

Professor Charles E. Fay wrote me in 1895 that the glacier had receded since 1890, and markedly since 1894. Photographs taken by Messrs. Parker B. Field and Philip S. Abbot in 1895 and 1896, respectively, show that the recession continued last year.

There are prospects that more systematic observations of some of the glaciers of the Pacific slope may be begun next summer.

HARRY FIELDING REID.

GEOLOGICAL LABORATORY,
JOHNS HOPKINS UNIVERSITY,
April 8, 1897.

[1] Probably due to an advance.— H. F. R.

[2] Captain Marshall Hall, to whose interest and energy the international committee owes its existence, represented the British colonies until his sudden death in April 1896.

A SKETCH OF THE GEOLOGY OF MEXICO.

MEXICO is a country whose geology is very little known even by its nearest neighbors. It nevertheless offers a wide range of interesting problems. Its geology has been much misunderstood and this must be the excuse for presenting here a résumé of a portion of the very interesting report[1] recently published by the Geological Institution of Mexico. Aside from the itineraries with detailed observations, the report includes a synopsis of the geology of Mexico by the Director Sr. Jose G. Aguilera. In the following pages is a very much abridged translation, or abstract of Professor Aguilera's paper. The original is accompanied by a small scale map on which the geology is spread over the areas left blank on the older map of Castillo[2] and the whole forms a notable contribution to the geology of the region as well as being perhaps the best general summary of the present state of our knowledge of the subject.

Geographically Mexico may be considered as consisting of a central tableland sloping to the north and northeast, and inclosed between two ranges of mountains which are separated from the oceans by strips of lowland narrowing to the south. The two mountain ranges unite in the central portion of the country, rising above the lower land in the form of a colossal V, the arms of which continue into the United States as the Rocky Mountains and Sierra Nevada. The united range continues south into Central America with the low tableland of Yucatan, to the east rising thirty to forty meters above the sea.

The central tableland or Mesa de Anáhuac with an area of about 666,000 kilometers and an average altitude of about 1700

[1] Bosquejo geológico de México, Bol. del Inst. Geol. de México, Nums. 4, 5 y 6. 270 pp., 5 pl., map. Mexico, 1897.

[2] Bosquejo de una Carta Geológica de la Republica Mexico formada par disposicion del Secretario de Fomento, 1889.

meters, continues without interruption from the high plains of Texas and New Mexico to the valley of Toluca, which rises against the flanks of the Nevada de Toluca, reaching an altitude of about 2630 meters. This great meseta forms a geographic unit of the first order. Breaks in the bounding mountains afford easy communication with the coastal region and furnish outlets for the drainage. It is a continuation of the Great Basin region and has all the characteristics of that area. To the north it widens and decreases in altitude; to the south it narrows and rises. At its vertex are situated the City of Mexico and the two great volcanoes of the country.

In Archæan time the southern, and a part of the western coast of Mexico, rose above the waters and formed a series of islands or perhaps a single strip of land which, as with the northern portion of the continent, served as a point of initial deposition, and around which has been laid down in successive geologic times the beds which now make up North America. The rocks of this period are numerous and present many variations between different types. In the southern portion of Puebla, in Guerrero and Oaxaca where the greater number of exposures occur, their order of deposition was as follows: (*a*) Porphyritic gneiss similar to augen-gneiss, losing its schistosity below and passing into a species of granite; (*b*) Phyllite gneisses resting upon and grading into the preceding beds; (*c*) Mica schists somewhat abundant, at certain points garnetiferous and comformable with the rock below; (*d*) Phyllites, very argillaceous in their upper portion, but with the clay gradually diminishing toward the base and with concordant structural variation from stratiform to schistose. These beds rest upon chlorite, sericite and amphibole schists, which in turn cover the phyllite gneisses.

Later than the deposition of the argillaceous phyllites and before the end of the Palæozoic, there were numerous eruptions in the following order: (1) Gneissic granite, passing into a porphyritic granite which cuts the mica schists without penetrating the phyllites. These rocks are shown in the northwestern portion of the republic in the City of Caborca, Sonora. (2)

Granite proper, cutting the mica schists and the phyllites and shown at most of the Archæan exposures as well in the northwest as the southern portion of the country. (3) Granulite, cutting all the rocks of the Archæan. (4) Hornblende-granite in frequent dikes and occasional stocks, cutting all the Archæan rocks. (5) Pegmatite, passing into graphic granite and occurring as dikes cutting the gneissic and true granites. There seem to have been two distinct periods of eruption of the pegmatite. The older, seen in Sonora, cuts only the gneissic granites, the mica and the amphibole schists. The later and more common type cuts all the Archæan rocks. (6) Greisen, associated with the granites, forming segregation veins. (7) Diorite dikes, later than the preceding rocks but earlier than the end of the Palæozoic. These are very abundant in the southern portion of Puebla and the northern part of Oxaca and Guerrero.

The Archæan forms considerable areas, and in addition to the points mentioned is found in Zacatecas near Fresnilo, in Guanajuato in the vicinity of the capital, in Sinaloa, near the crest of the Sierra Madre, and near Vera Cruz. The rocks also form the axis of the peninsula of Lower California.

The Palæozoic has few representatives in Mexico. The rocks of this system whose age is definitely fixed belong to the Carboniferous. Although considerable areas have been referred heretofore to the Silurian, and fossils characteristic of this terrane and said to be from Mexico, may be found in collections, we know of no exposures proven to be of that age. In the collection of the Institution is a piece of limestone holding beautiful specimens of *Orthis testudinaria* Dalman, and sent to Professor Castillo from the Cuesta de Santa Teresa near Cachuamilpa in Guerrero. Careful search in the locality by Professor Castillo failed, however, to reveal the source of the specimen. Many geologists have assigned to the Silurian the slates found at Guanajuato, Catorce and Zacatecas. Those at Catorce are Jurassic, and while at the other localities there are beds older than the Jurassic, there is no good reason for assigning to them so great an age as the Silurian. With regard to the Devonian Professor

Aguilera has succeeded no better than in searching for the Silurian. A careful study of localities said to have furnished Devonian fossils has only resulted in showing the presence of certain pre-Jurassic rocks whose age, because of the absence of fossils, and the metamorphism which the rocks have suffered, cannot be definitely fixed.

Carboniferous rocks of undoubted authenticity occur along the Guatemala border directly below the Cretaceous. The rocks are compact ash-gray limestones, containing *Productus semireticulatus*. Large areas of rocks in the central and northern portion of the country, assigned by Frazer, Hall and others to Silurian, Devonian and Carboniferous, are now known to be either Cretaceous or of unknown age.

In the absence of rocks belonging to the first two periods of the Palæozoic, it seems probable that Mexico, which during the Archæan was reduced to a group of islands, or perhaps to a single narrow peninsula stretching from California to Tehuantepec and Chiapas, suffered during the Silurian and Devonian a continuation of the ascendant movement which began at the end of the Huronian. The complete absence of stratigraphic and palæontologic data relative to the first subdivision of the Permo-Carboniferous authorizes the belief that during this time the elevation continued, and makes acceptable the hypothesis that it was during this time that the various islands became united and formed the skeleton of the country.

The Mesozoic is represented in Mexico by beds of the Upper Triassic and Jurassic, as well as the whole of the Cretaceous. The Triassic beds indicate a period of depression. The sediments accumulated in marshes and estuaries along the western coast to a thickness probably of 1000 meters; sediments 600 meters in thickness being now found in Sonora. The deposition was interrupted by minor elevations as is shown by lithological variations and the presence of basal conglomerates. The deposits cover a considerable area and are composed mainly of gray, red and yellow sandstones and gray to black slates. In general the rocks outcrop on the crests of low hills and ridges, being

uncovered and resting upon crystalline schists, granites and similar rocks, or are intercalated between the Huronian rocks and the arenaceous marls and slates of the Upper Jurassic. The latter is especially true south of Acatlán and about Tezoatlán. In some instances the Triassic is covered only by the Cretaceous or the Tertiary.

The position of the rocks along the Gulf of California and in the territory of Puebla and Oaxaca indicates that after their deposition they were subjected to an elevation which, continuing to the present time, has placed them more than a thousand meters above sea level in Puebla and more than two thousand in Oaxaca. In spite of the evidence of the invasion of the sea in the Triassic, the absence of marine sediments makes it impossible to trace the old shore lines, but the same absence indicates that the land then extended notably more to the west than at present and that the deposits then made along the coast have since been buried.

While the deposits of the Triassic were made in marshes and lagoons, some of which perhaps communicated with the sea, those of the Jurassic are in general such as denote continental seas and deep water. Certain of the Jurassic rocks, however, seem to have been deposited in an interior sea of slight depth. At the close of the Triassic the northwestern and southern parts of the country were elevated, draining the marshes. At the same time the southeast sank beneath the Lower, and later the Middle Jurassic seas. At the close of the Middle Jurassic there was a further land movement and the Upper Jurassic sea crept in over large portions of Coahuila and Oaxaca. The Jurassic rocks are conformable with the Cretaceous and are intimately folded with them.

The Cretaceous rocks cover much the greatest portion of Mexican territory. They include three well-marked series of beds, the Lower, Middle, and Upper Cretaceous. These correspond respectively the Lower to the Neocomian, the Middle to the Cenomanian, Turonian and a portion of the Senonian, and the Upper to the Danian, and a part of the Senonian of Europe.

The beds of the lower division are largely shales, clays, marls, and greensands. The middle formation is mainly made up of compact ash-gray limestones frequently magnesian, though not in general constituting true dolomite. The limestones are rich in fossils, though they have been much metamorphosed. The upper member occurs only in the northeastern portion of the country and is represented by fine to medium grained, gray to red and yellow sandstones, alternating with clay shales of gray to black colors.

The advance of the sea begun in the Jurassic, continued until the country was converted into an archipelago at the end of the Middle Cretaceous. There was then a general elevation, carrying all but the northeastern portion of the country along the Rio Grande, above the sea. This elevation was accompanied by folding and mountain-making, continuing into the Upper Cretaceous. It was at this time that the main masses of the Sierra Madre of the east and west coasts were ridged up.

The Upper Cretaceous was laid down by a retreating sea and by the close of the Mesozoic, Mexico had its present general outline. There were, however, certain differences. Although the country then as now formed a great triangle with the apex in Central America, the width of the landmass was much less than at present. The Pacific coast line was farther west and Lower California was not yet separated from the mainland. The Gulf of Mexico had a more irregular coast line and extended to the west and southwest, probably uniting with the Pacific south of Guatemala. Yucatan and Florida were as yet covered by the ocean.

During the Eocene there was a series of vertical oscillations, but the total result was an increase of territory. In the Miocene there was along the east coast an invasion of the sea, though not so as to cover the whole of the Eocene area. At the same time the Pacific advanced inland and the first peninsula of the Republic was cut off, forming Lower California. Toward the close of the Miocene a new movement of elevation in the Atlantic region caused the sea to abandon most of its former dominion, the ele-

vation terminating at the beginning of the Pliocene with the emergence of the peninsula of Yucatan and all of the southern part of the country which at the beginning of the Cenozoic had been buried beneath the waters of the two oceans. Upon the Pacific coast the depression seems to have continued in the Pliocene, so that Lower California was for a time cut off from Upper California by a canal and thus formed an island. On the Atlantic coast the Pliocene included a period of elevation succeeded by one of depression and in turn followed by an elevation, the latter continuing into the Quaternary.

It is not possible to fix absolutely the age of all the Tertiary beds. Those west of Laredo in the Rio Grande valley seem to belong to the Timber Belt beds of the Lower Claiborne of Harris. East of the same place are beds in part Eocene, and in part Miocene, possibly Lafayette. In the peninsula of Lower California, particularly along the Pacific coast, is a series of shallow water deposits resting upon the trachytes, andesites and dacites of the Eocene and containing pebbles of rocks erupted in the Miocene with fossils of Pliocene character. Along the Gulf of Mexico are Tertiary marine sediments made up of incoherent shell conglomerates and compact limestones. In the upper portion these contain fossils which in other parts of the continent are Miocene, mixed with recent and Pliocene forms. In the lower part the Miocene forms dominate.

The Tertiary in Mexico, as in the western portion of the United States, was a period of great eruptive activity. The wide variety of rocks and the large masses extruded are equally astonishing. Syenites, hornblende-diorites, quartz-diorites, diabases, porphyritic andesites, mica-andesites, dacites, and basalts are all present. With the andesites are trachytes, rhyolites and obsidians, and many transition varieties are present throughout the series. The eruptions begun in the Tertiary have continued to the present and have had much to do in shaping the topography of the country. The whole of the eruptive rocks are treated separately by Sr. Ezequiel Ordoñez.

H. Foster Bain.

EDITORIAL.

THE George Huntington Williams Memorial Lectures were fittingly inaugurated last month by the course of six lectures delivered by Sir Archibald Geikie at the Johns Hopkins University. The establishment of this memorial is due to the generosity of Mrs. George Huntington Williams, who provides in this way for a series of lectures to be given by geologists from various parts of the world on topics of interest to advanced workers in geology. No more appropriate introduction to what we hope may become a permanent source of inspiration to living geologists, while it will be a perpetual memorial of Professor Williams, could have been chosen than the subjects selected by Sir Archibald Geikie for his lectures — The Founders of Geology. Reviewing the beginnings of the science and the ideas and conceptions of those early workers, he not only presented a worthy introduction to a course which will deal largely with modern views and advanced theories, but he placed within easy reach of many a knowledge of ideas which may have appeared as new to us, but which in reality presented themselves to the earliest investigators. And in selecting an historical subject he followed a line which would have been most attractive to Professor Williams himself, and one in which he was peculiarly successful. Those of us who were prevented from hearing the lectures look forward to their publication with great interest.

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THROUGH the courtesy of the Governor of Maryland and of other state officials, and through that of the presidents of the railroads in the state, Professor Wm. B. Clark, the state geologist, was able to conduct several excursions into various parts of

Maryland, which were attended by Sir Archibald Geikie and the visiting geologists. They included an examination of the Cretaceous and Tertiary deposits along the Chesapeake Bay, the coalfields of Alleghany county, the Silurian and Devonian formations of the Appalachian district of the state, as well as the Cambrian strata of the Blue Ridge, and the pre-Cambrian volcanic rocks of South Mountain. Opportunity was thus given to become acquainted with the geological features of the state, which were first brought into prominence by the investigations of Professor Williams and his associates, and are now being further developed by the workers on the state survey under the direction of Professor Clark.

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Sir Archibald Geikie, as Director General of the Geological Surveys of Great Britain and Ireland, was prevented by the urgency of his duties at home from spending as long a time in this country as his friends here would have wished. The heartiness of his reception at those places he was able to visit may be taken as a guarantee of the high esteem in which he is held throughout the country. The hospitality shown him in Baltimore was repeated in Washington, Philadelphia, New York, and Brooklyn, in several of which places he delivered addresses. The lectures at the Johns Hopkins University attracted geologists from widely distant parts of the country and were well attended, and Mrs. Williams is to be congratulated upon so successful an inauguration of the memorial lectureship.

J. P. I.

Reviews.

Some Queries on Rock Differentiation. By G. F. Becker. Amer. Jour. Sci. (4), Vol. III, pp. 21–40, January 1897.

In this discussion Dr. Becker views his subjects from the physico-chemical side. He attempts to apply some of the results of Van t'Hoff, Oswald, Nernst, and other investigators to the question, "How may rock segregate into portions of distinctly different, yet of allied composition?" He thinks that differentiation, or segregation, as he prefers to call it, can occur only in two ways: (1) By the increasing or decreasing the concentration of certain components, caused by variations in temperature or pressure, which exist in different portions of the magma. These components are thought to be dissolved in the remainder of the liquid rock, and to obey the laws of dilute solutions. (2) By separation into two immiscible liquids due to changes in temperature and pressure. These take place by means of molecular flow, or diffusion, and he thinks convection would hinder this segregative process. He gives as instances of molecular flow the diffusion of salts in water, and explains the relation of osmotic pressure and diffusion to gas pressure and diffusion, and mentions that the three fundamental laws of gases, viz., Boyle's, Gay-Lussac's and Avagadro's have their parallels in three similar laws of solution.

Two cases of diffusion are next considered: (1) The diffusion caused by heating a solution at the top. (If the solution is heated at the bottom, convection commences and segregation is prevented.) (2) By a difference of pressure at the bottom from that at the top. Any diffusion caused by differential pressure would be too slight to have any appreciable effect. As to (1) it will appear from arguments yet to be presented that the diffusion will be so slow that in entire geological periods no effective change of composition would be possible. In his paragraph on the character of diffusion he states the units by which diffusion is measured, and that the rate of diffusion is expressed by the same mathematical formula as is the conduction of heat.

However this law only holds for dilute solutions, and he attempts to show that magmas are such dilute solutions.

Applying the foregoing to the rate of diffusion under the assumption that the solvent fluid is kept at constant composition and the dissolved substance is diffusing through it, he calculates the speed of the diffusion of various salts in water. He finds that common salt will diffuse fast enough to semi-saturate water at a distance of 1^{cm} in one day and 100 meters in 270,000 years. From certain observations he infers that lavas are at least fifty times as viscous as water, and therefore diffusion in such a substance would be fifty times as slow as that in water. Taking copper sulphate as the salt whose speed of diffusion should be multipled by fifty to represent the rate of diffusion in an average magma, he finds that in a million years there would take place a diffusion sufficient to impregnate the magma for forty-nine meters, and semi-saturate it to a distance of twelve meters. Finally he dismisses the hypothesis of the diffusion of miscible liquids because (1) diffusion is too slow a process; (2) a higher temperature is postulated at the top than at the bottom, and (3) because more or less convection is unavoidable, and he proceeds to consider diffusion of immiscible liquids.

He gives some examples of liquids which, above certain temperatures peculiar to each, are perfectly miscible, and below these definite temperatures separate into two immiscible liquids. This separation is accompanied by a sudden contraction of volume, and therefore all such separation is aided by increase of pressure. His points against such separation appear to be as follows: (1) The temperature of separation is first reached along the walls containing the magma, and therefore the separating component will condense on the containing walls much as frost and dew on good conductors of heat. Such a separation, however, involves molecular flow from the interior of the fluid to the walls, and therefore no large portion of even a moderately viscous magma could thus separate. (2) If the fluid does not condense on the sides, it must aggregate as a fog in the center of the fluid. This fog cannot condense farther, as a fog does in the atmosphere, on account of the great viscosity that he assumes the lava to have. (3) Magmas are not heated much above the melting point, and therefore the range in their temperature is not great enough to present much likelihood of their crossing the critical temperature of separation. This follows from the law of fusion that if a melted magma

receives an increase of temperature, this increment will be expended in melting more of the surrounding rock rather than in raising the temperature of the already molten mass.

Concluding, therefore, that his theoretical inspection proves that differentiation can at most play only a minor part in the explanation of consanguineous rocks, he advances his theory of the original heterogeneity of the earth.

The points advanced for such a heterogeneity are as follows:

1. The land and water hemispheres.
2. Anomalies in gravity.
3. Distribution of feldspars in the west.
4. Distribution of metallic ores.
5. The seeming permanence of continental plateaus show this heterogeneity to be original.
6. Condensation from nebulous ring would forbid perfect homogeneity.
7. The viscosity of the fluid earth would permit only a rude approximation to uniformity of composition.
8. Hypogeal refusion results in a re-formation of a heterogeneous liquid.
9. The transitional series of erupted lavas may be explained by chance mixing of unlike magmas.

No attempts will be made to criticise Dr. Becker's views on the heterogeneous composition of the earth. Many of his points are strong, and have been advanced by others against the conception of a primitive homogeneous earth. Yet his application of physico-chemical principles is open to investigation.

Dr. Becker is doubtless correct in his conclusion that any change in relative concentration of *miscible liquids* by means of differential pressure or temperature is inadequate to explain any considerable diffusion of a magma. Prior to Dr. Becker, Dr. Bäckström pointed this out very clearly. Nevertheless we may be permitted to examine some of the facts he cites and inferences he draws to prove this point.

He says there are only two conceivable ways in which differentiation may occur; either by segregation into miscible or into immiscible liquids, caused by differential pressure, or temperature or both. May not these two operations be assisted by the crystallizing of different double salts at different temperatures and pressures peculiar to each?

The brilliant investigations of Van't' Hoff along this line do not seem to have been applied as yet to the problems of petrology.

After showing that the law from which he calculates the rate of molecular diffusion is good only for dilute solution, Dr. Becker says: "Magmas must be regarded as solutions of a series of very similar substances, and it is known that in such cases the solubility of each is diminished by the presence of the others."

This law holds only for salts dissolved in a dielectric, and is due to equilibrium relations between free ions and the undissociated portion of the salts. By "a series of very similar substances" is evidently meant a series of salts the members of which have some common ion or ions. If the data in the paper on the change of electric conductivity observed in rocks of different composition, while passing from liquid to solid, by Carl Barnes and J. P. Iddings,[1] are sufficient to prove that there is electrolytic dissociation in igneous magmas, then Dr. Becker's method is correct, and we need only to examine his assumptions on the viscosity, etc., of the lavas. If these data are insufficient to close the subject then Dr. Becker is reasoning from premises not yet proved.

Admitting, however, that the weight of evidence is with Dr. Becker on this point we may examine his views on the viscosity of lavas, for although of importance to his conclusions regarding segregation of *miscible* liquids, the value of his objections to segregation of *immiscible* liquids, depends upon the correctness of his assumptions on this point. He states that "There is some reason to think that the viscosity of even the most fluid lavas is more than fifty times as great as that of water." This is drawn (1) from a comparison of the speed of the flow of lava from Kilauea, with that of a stream of water of the same cross section and flowing down a slope of the same grade. (2) Since banded rhyolites show no diffusion of their layers into each other, it follows that if they had viscosity fifty times that of water they would show appreciable diffusion.

It does not seem probable that the viscosity of an extruded lava would be the same as that of one highly treated and supercharged with vapors. The erupted lava has crusts forming on both outer and inner surfaces. It has lost much of its superheated steam and other vapors, and more or less crystallization has already started throughout its mass. The unerupted lava is permeated with superheated gases, and is at a very high temperature. Of course pressure increases the viscosity and

[1] Amer. Jour. Sci. (3), XLIV, 242–249. 1892.

we do not know where the increasing pressure overtakes the effect of increasing temperature and superheated gases, and therefore we may expect some lavas to be very liquid, and to permit considerable molecular flow, while in others the viscosity might be so great as to prevent all such diffusion. Therefore is the assumption that the viscosity of unerupted lavas is the same as that of an erupted and cooling sheet warranted, and is there not a possibility of both far greater and far less viscosity than that assumed by Dr. Becker?

We have, moreover, positive evidence that lavas may be very fluid if the pegmatitic structure in the rocks of Christiania described by Brögger as igneous be so, as he affirms for his region at least. Also the intrusion of erupted matter for long distances along planes of fissibility, in the Archean rocks of the Lake Superior region, demands more or less fluidity. If the alternate layers of banded rhyolites have a different amount of absorbed water vapor, as Professor Iddings suggests, this phenomenon might better be considered, as the result of impregnation of the magma by vapor shortly before its eruption. Moreover the fact that in the banded rhyolites we do not have diffusion between the layers is no proof that under other conditions we should not have such diffusion. Some magmas have been erupted under such conditions that they are perfectly homogeneous, while others show marked differentiation.

We reiterate that Dr. Becker is correct in concluding that differentiation into miscible liquids could play only a subordinate part in rock segregation. His attack on the theory of differentiation into immiscible liquids seems open to question; for the separation must instantly begin throughout the portion that has reached the critical temperature. This separation will start at many different centers, as in crystallization, and since molecular flow is rapid for short distances, and very slow for longer distances, this operation would be rapid. When these immiscible liquids are once formed, flow, stirring, gravity, etc., will help aggregate like to like. This segregation may be still farther assisted by the temperature sequence of crystallization of double salts.

His point, that lavas are too viscous to permit such separation and aggregation, has been already answered. His third point, that we cannot have wide enough range of temperature for this mode of separation, following from "the law of fusion," may have force in some instances, but where we have considerable mass of magma there

could be a large increment of heat as we approach the center. To sum up the whole matter, his objections to the segregation of *miscible* liquids are qualitatively correct, but the quantitative accuracy is impaired by the nature of the assumptions on which the estimate is based. These assumptions are thought to be incorrect in some instances, and in all cases to lack the positive proof necessary for a scientific demonstration.

It seems unnecessary to assume that when *immiscible* liquids are formed segregation can only take place along the walls, and therefore involve extended molecular flow.

Instead of this we conceive that the process may resemble crystallization and take place at many centers, and therefore involves molecular flow through short distances. All stirring, currents, etc., instead of hindering, would aid in this case.

Finally, we have the fact of a regular rock gradiation established; a gradiation which is too widespread and uniform to be explained by an original heterogeneity of earth, and a chance mixing of the lavas. Our present knowledge, and the data at hand, are probably too meager to exactly explain the processes by which such gradation was accomplished. Yet, we may not affirm, with Dr. Becker, that rock differentiation is impossible under the known laws of physico-chemistry.

The problem will doubtless yield when attacked by the methods of modern physics and chemistry, and for this reason Dr. Becker's paper is most timely. CYRUS FISHER TOLMAN, JR.

An Introduction to Geology. By W. B. SCOTT. The Macmillan Company. 1897. 573 pp. $1.90.

The preparation of a satisfactory text-book on any subject so large as geology must always be a difficult matter. There is so much difference of opinion as to where emphasis should be laid, as to what should be said and what omitted, and as to the order in which the topics should be treated, that no book is likely to command universal approval in all respects. Yet in spite of all the difficulties Professor Scott has succeeded in preparing a book which will command respect and probably very general approval. He has shown in its preparation a sense of proportion which the makers of text-books sometimes fail to exhibit. When to this is added that he has made use of the newer literature throughout, so that the book is up to date, it will readily be inferred

that the book is likely to prove a useful one in institutions where brief courses in geology are taken by somewhat mature students.

The book perhaps departs as much and as satisfactorily from the text-books heretofore in use, in its treatment of the later parts of historical geology, as at any point. In his treatment of the Mesozoic and later periods, the author has brought together much data not heretofore incorporated in a text-book, and his handling of that difficult part of the subject is much more satisfactory than that found in most text-books of corresponding scope.

The illustrations in the volume are mainly new and attractive, many of them being reproductions from photographs direct. The illustrations of fossils seem to have been selected with great care, but are, on the whole, fewer in number than could have been wished.

The publishers have done their usual excellent work in the preparation of the volume. R. D. S.

Missouri Geological Survey, Vol. XI; Clay Deposits. By H. A. WHEELER. 622 pp., 39 pl. Jefferson City, 1896.

The eleventh volume issued by the Missouri Survey is well up to the standard of the previous work. It is a report of much more than local interest, and will doubtless become the standard book of reference for clay workers, filling a position analagous to that of the Manganese Report of the Arkansas Survey. The Missouri clay report is the most comprehensive work treating this subject issued by any American state since the New Jersey report of 1878. It monographs the subject of clays and clay working as exemplified in the wide range of deposits and processes in Missouri. It is written from the point of view of the engineer and treats of the different clays as adapted to various uses. Nevertheless there are many geological problems whose solution will be the easier for it. The large number of new analyses, as well as the careful tabulation of a wide range of older ones is alone a feature of great value. The physical tests, the studies of fusibility, plasticity, and shrinkage, aside from their immediate practical importance, may be used to advantage in studies of the origin of mountains and of mountain-making forces. Probably few portions of geology are less understood or more complex than that which relates to metamorphism, and in order to understand the nature of metamorphic rocks it is necessary to have something more than a general notion of the nature of the

metamorphosed material. This has been recognized so far as the petrology of igneous rocks is concerned but the petrology of the sedimentaries, being less inviting, has been largely neglected. It seems probable however that the field will eventually yield important results and certainly until it is better understood dicta regarding the metamorphism of sedimentary rocks must rest largely on assumption. Professor Wheeler's report was not undertaken with this point in view, and yet his results often have considerable bearing on the subject. His work will also, it is believed, prove helpful because of the methods of study and measurement which he has formulated.

To one not already familiar with the trade, the wide variety of products and the extent of the clay industry in Missouri, will doubtless come as a surprise, and yet among the most valuable portions of the report are the suggestions with regard to the expansion of the industry. If these be followed the state will soon receive returns many times in excess of the cost of the work. H. FOSTER BAIN.

The University Geological Survey of Kansas. By ERASMUS HAWORTH and Assistants. Vol. II, 318 pp. 25 plates. Topeka, 1897.

Under the direction of Professor Erasmus Haworth the University Geological Survey of Kansas has published a second volume upon the geology of that state. It is a companion and supplement to volume one, and covers the western half of the state as the former covered the eastern portion. It deals chiefly with the stratigraphy of the Upper Permian, Cretaceous and Tertiary formations, and while it affords much valuable information to the geologist it is written primarily for the citizens of the state. In the preparation of the volume Professor Haworth has enlisted the coöperation of Professor C. S. Prosser of Union College, Schenectady, N. Y., with his two assistants Mr. J. W. Beede and Mr. C. N. Gould, Professor S. Williston of the State University, and Mr. W. N. Logan. The report is illustrated with numerous half-tone reproductions from photographs, geologic sections and maps.

The first paper is on the "Physiography of Western Kansas" by E. Haworth. The drainage of the region as a whole is considered and the present drainage is compared with that of Tertiary time. Follow-

ing this general treatment each of the individual streams is discussed in greater detail.

The next paper is by Professor C. S. Prosser upon "The Upper Permian and the Lower Cretaceous." Professor Prosser's work upon the Permian of Kansas is well known, and that portion of the present paper devoted to the Permian is but a supplement to what he has previously published. The "Red Beds', or Cimarron Series come in for consideration here. These beds have been placed by different workers in the Permian, Jura-Trias and Cretaceous. The entire absence of fossils in the series in Kansas makes their correlation at best uncertain. The presence of Permian fossils in the "Red Beds" of Texas, however, which have a similar position but differ lithologically, the seeming conformity with the true Permian below and the marked unconformity with the Cretaceous above, point to the Permian or Triassic age of the series, but Professor Prosser states that the correlation of the beds with either the Permian or the Triassic is as yet a matter of uncertainty. The second part of Professor Prosser's report is upon the Lower Cretaceous, which is represented in Kansas by the Washita division of the Comanche Series. The stratigraphy of the formation is discussed in detail, many sections and lists of fossils being given.

A chapter on "The Upper Cretaceous of Kansas" is contributed by W. N. Logan. The series is well represented in western Kansas by the Dakota, Benton, Niobrara, and Fort Pierre groups. Each of these formations is discussed in more or less detail.

The next paper is by Professor S. W. Williston upon "The Kansas Niobrara Cretaceous. This is followed by the "Physical Properties of the Tertiary" by Professor E. Haworth, in which the stratigraphy, lithology, origin and mode of formation of the Tertiary is considered. "The McPherson Equus Beds" are described by Professor Haworth and J. W. Beede. These beds have been considered as of glacial origin. This explanation of their origin is disputed by the authors and they state that no satisfactory interpretation of them can as yet be advanced. The last chapter in the volume is by Professor Williston upon "The Pleistocene of Kansas." The deposits of this age are treated briefly and mention is made of the various vertebrate remains which have been found in them. S. W.

Preliminary Report on the Marquette Iron-Bearing District of Michigan. By CHARLES RICHARD VAN HISE and WILLIAM SHIRLEY BAYLEY. *With a Chapter on the Republic Trough.* By HENRY LLOYD SMYTH. U. S. Geological Survey, 15th Ann. Rept., pp. 477–650, pls. 13–26, figs. 9–20; 1895.

The Marquette district, the oldest important iron district in the Lake Superior region, is well known to students of pre-Cambrian geology, and while it has been studied in detail before, the present report represents the first systematic and successful attempt to unravel the structure of the region and to determine the sequence and relations of the various rock bodies. The key to the structure of this district, which is in general the key to the structure of much of the Lake Superior region, has been known for several years; it is that below the Keweenawan are three unconformable rock series, frequently so closely folded together that their separation is very difficult. These three series are the Archean, the Lower Huronian, and the Upper Huronian, or, as termed in this report, the Basement Complex, the Lower Marquette, and the Upper Marquette.

The district studied extends from the Lake Superior shore just south of Marquette westward to Michigamme, a distance of over thirty-five miles; it is nine miles in width, but in places much more than half of this distance is occupied by rocks of the Basement Complex, and has not been studied in detail. The Lower and Upper Marquette rocks occur in a basin flanked on either side (north and south) by the Basement Complex, which is composed of an intricate mixture of granites, gneisses, schists, and surface volcanics, all thoroughly crystalline, and cut by basic and acid dikes.

The Lower Marquette is separated into six conformable formations as follows, in ascending order: Mesnard quartzite, Kona dolomite, Wewe slate, Ajibik quartzite, Siamo slate, and Negaunee formation. During Lower Marquette time the transgression of the ocean was from the east, so that the lower formations are represented only in the eastern part of the district, and on going westward higher and higher strata are found, resting directly on the underlying Basement Complex, between which and the Lower Marquette there is a marked unconformity. The Negaunee is the Lower Marquette iron-bearing formation, and is composed of sideritic slates, grünerite-magnetite schists, ferruginous slates, ferruginous cherts and jaspilite, all of which are

genetically related. With the Negaunee are masses of basic igneous rock, both extrusive and intrusive, the latter being the more common. There are three classes of ore deposits, one at the bottom, one within, and one at the top of the iron-bearing formation. The first two are generally of soft hematite, while the third, which is associated with the uppermost part (jaspilite) of the iron-bearing formation and passes up into the lower part of the Upper Marquette, is of hard hematite. In origin the ore is the same as in the Penokee-Gogebic range, *i. e.*, it is derived from an original sideritic chert, and has been concentrated in certain positions by percolating waters, and the silicious portions of the rock have been removed from these areas of ore concentration. The ore bodies lie in pitching troughs formed of comparatively impervious rock, as slate or basic dike rock, or both.

The Upper Marquette, resting unconformably on the Lower Marquette, is divided into the Ishpeming, the Michigamme and the Clarksburg formations. The first is composed of the Goodrich quartzite and the Bijiki schist, the latter of which is a grünerite-magnetite schist. Small ore bodies occur near the top of the schist and also in the Michigamme formation. The Clarksburg is composed of volcanic material, and the volcanic activity is thought to have begun during the time of deposition of the Ishpeming formation, and this igneous material is regarded as replacing, where it occurs, the upper part of that formation and the lower part of the Michigamme.

The Republic trough is a syncline with the axis nearly horizontal and running in a northwest-southeast direction. The three unconformable series described in the Marquette area are here represented, but of the Lower Marquette only two upper members are present, and the Clarksburg formation of the Upper Marquette is lacking. The iron ore deposits, which are of magnetite and hematite, are in the upper part of the Lower and the lower part of the Upper Marquette.

In structure the Marquette district is complicated, the rocks having been subjected to severe folding. The general structure is a broad complex synclinorium, in which the folds have an east and west direction. At the edges the folds are sharply overturned, and on going toward the center higher and higher beds are encountered. The structure is similar to the composed fan folds of the Alps, except that the whole has sagged down, forming a synclinorium rather than an anticlinorium; to this the name of Marquette type of fold is applied. In

addition the rocks have been compressed more or less closely by a force acting in an east-west direction.

This report represents a vast mass of most detailed examination in the field and in the laboratory, the completed form of which is to be expected as a monograph of the U. S. Geological Survey. With this will be issued maps, on the scale of four inches to the mile, showing all outcrops and other details of structure and of topography. As already stated, this report is the first successful attempt to present the structure of the Marquette iron-bearing district, an area which has been much studied before, but most of whose problems have remained unsolved. While there are a few minor points yet unsettled, the major questions have been answered. The whole is a practical and successful application of the advanced methods and principles of structural geology applied to nonfossiliferous rocks, which methods and principles have been so masterfully presented by the senior author.

U. S. GRANT.

ABSTRACTS.

Geological Atlas of the United States. Folio 30, Yellowstone National Park, Wyoming, 1896.

The Yellowstone Park folio, recently issued, consists of six pages of descriptive text, three pages of illustrations, four topographic sheets (scale 1 : 125,000) and four sheets delineating the areal geology of the region.

The general descriptive text, giving a succinct narrative of the geological history and development of the park country from the time of the earliest continental land surfaces up to and including the hydrothermal phenomena as seen today, was written by Arnold Hague, geologist in charge. It is followed by an account of the sedimentary rocks, from the earliest Cambrian deposits to the Tertiary conglomerates, by Walter Harvey Weed, and a brief petrographical description of the igneous rocks, by Joseph Paxson Iddings. The area of country covered by the Yellowstone National Park folio lies between parallels 44° and 45° and meridians 110° and 111°. It is situated in the extreme northwest corner of Wyoming. By far the greater part of the park is included within the area of the four atlas sheets, but a narrow strip lies to the northward in Montana, and a still narrower strip extends westward into Idaho and Montana. In the organic act establishing the park, Congress declared that the reservation was "dedicated and set apart as a public park and pleasure ground for the benefit and enjoyment of the people." Owing to the marvelous display of geysers and hot springs, and such remarkable physical features as the Grand Canyon and Yellowstone Lake, this folio possesses more than an ordinary interest to geologists.

The central portion of the Yellowstone Park is a broad volcanic plateau, with an average elevation of 8000 feet, surrounded on nearly all sides by mountains rising from 2000 to 4000 feet above its general level. The continental watershed crosses the park, separating the waters of the Atlantic from those of the Pacific, the Missouri and the Columbia, by the way of the Yellowstone, and the Snake, finding their sources on this plateau.

The oldest rocks of this region are granites, gneisses, and schists regarded as of Archæan age. They occur in all the mountain uplifts that encircle the park, but are unknown in the central portion. Around these ancient continental land masses there was deposited a conformable series of sandstones, limestones, and shales extending from the time of the Middle Cambrian, the lowest beds exposed, through the Upper Cambrian, Silurian, Devonian, Carboniferous, Juratrias, and Cretaceous, including the Laramie sandstone. Nearly all these great divisions of Palæozoic and Mesozoic times are characterized by a typical fauna.

With the close of the deposition of the Laramie sandstone the conformable series of sediments came to an end. The entire region was elevated above the sea, the movement being accompanied with plication and folding of strata. This primary orographic uplift which blocked out the main ranges of the northern Rocky Mountains, has been designated the post-Laramie movement.

Tertiary sedimentary rocks occupy only small areas in the park, the greater part of the region being covered by extensive flows of lava. A heavy mass of coarse conglomerate, designated the Pinyon conglomerate, has been referred to the Eocene; and Pliocene conglomerate and coarse sands are well exposed in the escarpments of the Grand Canyon.

Volcanic energy, which has played so great a part in the geological development of the country, was connected with the post-Laramie movement and followed closely upon the elevation of the mountains, and the accompanying dislocation and compression of strata. The eruptive masses, in forcing their way upward, sought egress along lines of least resistance, or wherever strain has been greatest in the crumpled sediments. Volcanic outbursts continued on a grand scale throughout Tertiary time.

During the Eocene and Miocene periods enormous volumes of fragmental ejectamenta, largely composed of andesitic and basaltic breccias, were thrown out. The Absaroka Range was almost wholly built up of volcanic material. Evidence of this long-continued action is shown in the well-preserved fossil floras of Eocene and both Lower and Upper Miocene age. The famous fossil forests of the Yellowstone are of Miocene age. After a period of great erosion the depressed basin lying between the encircling ranges was transformed into the present Park plateau by the extravasation of immense flows of rhyolite

of Pliocene age. Still later the recent basalts, the last of the igneous extrusions, poured out over the rhyolite along the ridges of the plateau. A generalized vertical section accompanies the text, showing the order of succession of the extrusive flows, from the earliest outbursts to the final dying out of eruptive energy. It is shown that long-continued currents of heated waters and acid vapors have acted as powerful agents in decomposing the igneous rocks of the plateau, and date back to Pliocene time; at least they were active before glacial ice covered the country. Hot springs, geysers, and solfataras are closely associated with the rhyolite, and in fact thermal activity is confined almost exclusively to areas of this rock.

The illustrations relate mainly to the occurrence of both active and dormant geysers and hot springs or some phase of volcanic geology. The Grand Canyon, well shown in the illustration, is a profound gorge cut in the Pliocene rhyolite, the brilliant coloring being due to the action of thermal waters.

Geologic Atlas of the United States. Folio 24, Three Forks, Montana, 1896.

This folio, by Dr. A. C. Peale, consists of five pages of text, a topographic sheet (scale 1 : 250,000), a sheet of areal geology, one of economic geology, one of structure sections, and one giving a generalized columnar section for the district.

The area covered comprises the square degree which lies between the meridians 111° and 112° and the parallels 45° and 46°, in the southwestern, mountainous portion of Montana, and includes 3354 square miles. In the extreme southeast corner the Yellowstone National Park barely falls within the area. The folio derives its name from the valley in which the Jefferson, Gallatin, and Madison rivers unite to form the Missouri. The "Three Forks" valley is important from an historic standpoint, as being the point which Lewis and Clark reached in July, 1805, when they named the three confluent branches of the Missouri.

The text begins with a general description of the geography and topography of the region, and then takes up the general geology. The oldest rocks in the region are the crystalline schists and gneisses, designated as of Archæan age, which in pre-Cambrian time formed a land mass comprising nearly all the area included in the map. While

the Algonkian beds were being deposited to the extent of from 6000 to 12,000 feet, there was a gradual subsidence of the whole region, and shallow seas for the most part prevailed. During the Palæozoic age there were many minor oscillations of the surface, which were more frequent during Cambrian time than during the deposition of the Devonian and Carboniferous limestones. Toward the close of the Cretaceous period a general elevation began, which was accelerated after the deposition of the Laramie formation. The formation of the mountain ranges, together with the subsequent erosion, resulted in many valleys, which eventually were occupied by fresh-water lakes. These lakes attained their greatest extent in the Neocene period, lasting in all probability until the Pleistocene period was well advanced, and during their earlier stages immense bodies of wind-carried volcanic dust were deposited in their waters, and are now seen as beds of pure white. At the same time the dust fell upon the surrounding country, from which it was afterward washed into the lakes, forming an upper series of yellowish and rusty colored beds. These dust showers destroyed both animal and vegetable life, and the remains carried into the lakes were buried in their deposits, where they are now found as fossil bones and opalized and silicified wood.

Under the "Description of Rock Formations" are outlined all the formations from the Archean gneisses up through the Algonkian, Cambrian, Devonian, Carboniferous, Juratrias, Cretaceous, Eocene, Neocene, and Pleistocene. The rocks of more than half of the area are of sedimentary origin, while the crystalline rocks occupy approximately 1000 square miles, the remaining third of the area being covered with igneous materials. Prominent among the latter are the andesitic breccias which form the main part of the Gallatin range, the great porphyritic laccolite occupying the center of the Madison range, and the basaltic plateau which lies west of the Madison valley.

Under the heading "Structural Geology," after a general consideration, the vertical and horizontal movements are discussed, and the development of the lake basins is described. The arrangement of the rock-mass is complex, the structure being complicated by laccolites, dikes, and surface flows of igneous material. Unconformities exist, showing that areas previously raised to land surfaces and worn down have subsided, have been crossed by an advancing shore, and later have passed beneath the sea. The great series of conformable strata is closely folded, and has been pushed up in arches, many of which have been

overturned from the effect of horizontal thrusts. The simple as well as the overturned synclines are marked by areas of Laramie Cretaceous beds, which, at the time of the folding, were the latest and highest of the formations. The arches between the troughs having been broken and exposed by the elevation, excessive erosion has worn them down to the older rocks, exposing the Archæan, which usually forms the axes of the uplifts. Unlike the Appalachian folds, which are strikingly parallel and continuous, these folds lie in various directions, due to several independent centers of uplift. Three great faults cross the Gallatin range, two of them extending across the Madison range to the extreme western part of the area. Following or accompanying the folding of the Cretaceous and pre-Cretaceous strata the detritus resulting from the greatly facilitated erosion, together with volcanic material erupted during this epoch, was deposited unconformably on the eroded upturned edges of the earlier-formed strata.

The lake basins are now the floors of extensive valleys separating the detached mountain ranges, which rise about 6000 feet above their bases. As the lake deposits are at least 2000 feet in thickness, the difference of elevation between the bottoms of the lake basins and the summits of the peaks must be at least 8000 feet. The region was a mountainous one before the development of the lakes, but in the evolution of the existing relief, movements and erosion have both operated to accent the topographic differences.

The principal economic resources of this region are gold, silver, iron ore, copper, limestone, and coal. The occurrence of coal in Devonian rocks on the north side of the Jefferson canyon is of geologic interest, although not of any great economic importance. The fine pumiceous volcanic dust found in the old lake basins has been utilized to a very limited extent as a polishing material. Brick clays occur, and are used to a small extent in a few localities, especially near Bozeman. In addition to the economic resources just referred to, the sheet of economic geology has indicated upon it the localities of building stone and mineral springs.

Geologic Atlas of the United States. Folio 29, Nevada City, special folio, California, 1896.

This folio, by Waldemar Lindgren, consists of seven pages of text, three special topographic maps (scale 1 : 14,400), the Grass Valley,

Nevada City, and Banner Hill; three corresponding maps showing the economic geology, and three others giving structure sections.

These maps, on a scale of about four inches to the mile, have been prepared to illustrate the detailed structure of the gold-mining regions in the vicinity of Nevada City and Grass Valley. Each of them comprises an area three miles wide by four miles long, the total area being nearly thirty-six square miles. The Nevada City and Grass Valley areas fall within the boundaries of the Smartsville atlas sheet, while the larger part of the Banner Hill area falls within those of the Colfax atlas sheet. The relief is that common to the middle foothill region of the Sierra Nevada — that is, the surface is a very irregular and undulating plateau deeply trenched by the canyons of the recent river systems.

Sedimentary rocks, chiefly referred to the Calaveras formation, occupy small, usually long, narrow areas imbedded in the predominating igneous masses. Granodiorite occupies a large part of the Nevada City and Banner Hill districts, while a small *massif* of the same rock is found in the Grass Valley district. Large areas of diabase, porphyrite, and brecciated forms of these rocks surround and separate the granodiorite areas. In the southwestern part of the Nevada City district and the northeastern part of the Grass Valley, a large and complicated *massif* is found, consisting in part of diorite, in part of gabbro, pyroxenite, and serpentine.

The slates of the Calaveras formation are the oldest rocks. Next younger are the diorites, gabbros, and serpentines. Still later are the diabases and porphyrites; and the intrusion of granodiorite closed the succession of igneous rocks. The bed-rock series is, as usual, in part covered by several hundred feet of Neocene gravels, and rhyolitic and andesitic tuffs, the gently sloping top of the andesitic ridges forming a principal feature of the landscape.

The Neocene auriferous gravels have been extensively worked in the Nevada City and Banner Hill districts, both by the drifting and the hydraulic processes, and considerable ground still remains which probably can be profitably worked. The gold-quartz veins are numerous and belong to several distinct systems. They are found in all of the formations represented on the sheet, and generally cross the contacts without change. In the Banner Hill district the veins are narrow but rich, and have a general east-west direction and a northerly or southerly dip. In the Nevada City district the quartz veins have a general north-south direction and an easterly dip of about 45°. Large

dislocations producing overthrust faults have occurred along several of the veins. In the Grass Valley district there is one system with a west-northwesterly direction and a steep northerly or southerly dip. On this system the celebrated Idaho mine is located. Most of the veins in the central and southerly part of the district have a northerly direction and a flat easterly or westerly dip. The veins are often accompanied by strongly developed sheeting of the country rock.

United States Geologic Atlas, Folio 28, Piedmont, West Virginia–Maryland, 1896.

This folio consists of six pages of text, signed by N. H. Darton and Joseph A. Taff, geologists, and closing with a series of vertical sections showing the positions and thickness of the coal beds; a topographic map; a sheet showing the areal geology of the district; another showing the economic geology; a third exhibiting structure sections; and a fourth containing a columnar section and a key to the synonymy of the various formation names. The maps are on a scale of 1:125,000.

The area represented is about 925 square miles. In Maryland it comprises the southern portion of Garret county and a small area in the southwestern corner of Alleghany county. In West Virginia it includes nearly all of Grant county, the western portions of Hardy and Mineral counties, the northeastern portion of Tucker county, and a narrow area of Preston county adjacent to the Maryland boundary line. Its southeastern corner is in a region of Appalachian ridges, and it extends northwestward over the Alleghany Mountains and the Upper Potomac coal basin to the headwaters of the Youghiogheny River, a branch of the Monongahela River.

The geologic formations comprise members ranging from the sandstones in the middle of the Silurian to the Upper Coal Measures of the Carboniferous. In the southeastern portion of the area there are two sharp anticlinal uplifts which bring up the Silurian rocks in two prominent mountains, New Creek Mountain and Patterson Creek Mountain. To the westward lies the coal basin which extends from the Alleghany front to the Backbone Mountain. Along its center is cut the deep gorge of the north branch of the Potomac River. The basin is a relatively shallow one, but it contains about 3000 feet of Carboniferous deposits. To the westward is the anticlinal region of

Devonian rocks which underlie the characteristic glade country about Oakland, Mountain Lake Park, and Deer Park. West of Oakland is another synclinal basin containing about 2500 feet of Carboniferous beds.

The geologic classification does not differ materially from that outlined by W. B. Rogers and others, but geographic names have been applied to all of the formations. The lowest members are a series of sandstones and quartzites, which have been referred to as "No. IV" and "Medina." This series has been subdivided into the Juniata formation, consisting of brownish red sandstones and shales; the Tuscarora quartzite; and the Cacapon sandstones, consisting of thin-bedded red sandstones. Next there is the representative Clinton formation, which has been designated the Rockwood formation, as in other folios; the Lewiston limestones, including representatives of the Helderberg and associated limestones, and the Monterey sandstones, Romney shales, Jennings formation and Hampshire formation, representing the Devonian deposits. As the last three formations are not sharply separated from each other, the patterns by which they are represented on the map are merged in a narrow zone along their boundaries. The Carboniferous period is represented by the Pocono sandstone; the Greenbrier limestone; the Canaan formation, which in a general way is a representative of the Mauch Chunk shales; the Blackwater formation, which represents the Pottsville conglomerate in greater or less part; the Savage formation and Bayard formation, which are the Lower Coal Measures; the Fairfax formation, or Lower Barren Measures, and the Elk Garden formation, a part of the Upper Coal Measures.

The principal coal beds are in the Savage formation, containing the "six-foot" or Davis coal bed; the Bayard formation, containing the coal bed known as the "four-foot" or "three-foot," or "Bayard" or "Thomas" coal; and the Elk Garden formation, containing the "fourteen-foot" coal bed.

On the economic sheet of this folio, the coal-bearing formations are strongly emphasized, and underground contours are introduced to show the lay of the "six-foot" coal bed in the Savage formation for each 100 feet. Other economic resources of the area are red hematite iron ores in thin beds in Rockwood shales and limestones at several horizons, of which the lower member in the Lewiston is locally available for cement.

United States Geologic Atlas, Folio 23, Nomini, Maryland-Virginia, 1896.

This folio consists of four pages of text signed by N. H. Darton, geologist, a topographic map of the district, a map showing the areal geology, and a map showing the distribution of underground waters and artesian wells. The scale of these maps is 1:125,000.

The area represented in this folio is about 938 square miles, which lies partly in Virginia and partly in Maryland. In Virginia it comprises nearly all of Westmoreland county, with parts of Essex, Northumberland, and Richmond, and in Maryland it includes portions of St. Mary, Charles, and Calvert counties. It lies entirely within the Coastal Plain area. The Potomac River extends northwest and southeast across the middle of the area, the Patuxent River crosses its northeastern corner, and the Rappahannock River crosses its southwestern corner. To the extreme northeastward it extends to the shore of Chesapeake Bay. These waters are all tidal estuaries. Along the river valleys there are wide, low terraces capped by the Columbia formation, of Pleistocene age. The intervening areas are plateau remnants capped by Lafayette deposits, of supposed Pliocene age. The underlying formations are the Chesapeake and Pamunkey, the latter extending from the westward only a few miles into the area, along the north side of the Potomac River.

The Pamunkey formation, of which only the uppermost beds are exposed, consist in greater part of glauconitic marls of Eocene age. It is overlain unconformably by the Chesapeake formation, which is characterized by fine sands, marls, and clays, portions of which consist largely of diatomaceous remains. The formation is very fossiliferous at some localities. Its age is Miocene. The greatest thickness which it presents in the Nomini area is about 270 feet, but it continues to thicken gradually to the eastward.

The Lafayette formation, which ranges from 25 to 40 feet in thickness, consists of sandy loams of orange, brown and buff tints often variegated, containing irregularly disposed bands and sprinklings of small quartzite pebbles and coarse sands. The pebbles and larger sand grains are orange tinted, mainly by superficial staining. The plateau surface, capped by this formation and deeply incised and dissected by the larger drainage depressions, inclines gently southeastward at an altitude ranging from about 190 feet along the northern and western border of the area to about 90 feet along its eastern

border. Its greatest altitude is 200 feet in a portion of Nomini cliffs. It has also in most cases a slight slope into each of the river valleys.

The Columbia formation is a deposit of loam merging downward into coarser materials containing beds of quartzite, gravel, and bowlders. Its thickness averages 20 feet. Its surface extends from altitudes of 5 to 60 feet above tide level.

The principal economic features are underground waters, which on the lower lands furnish flows for artesian wells. Three water-bearing horizons are known, one at the base of the Pamunkey, another 100 feet higher in the same formation, and a third in the lower sandy members of the Chesapeake formation. They all dip to the eastward at a very moderate rate. There are many artesian wells which obtain water supplies from 160 to 305 feet. On the artesian well sheet of the folio distinctive underground contours are given to show the depths below tide level of all of the water-bearing horizons.

Other economic resources of the area are marls in the Pamunkey and Chesapeake formations, diatomaceous deposits in the Chesapeake formation which are often sufficiently pure for commercial use, brick clays, potter's clays, sand and gravel.

Geologic Atlas of the United States. Folio 26, Pocahontas, Virginia-West Virginia, 1896.

This folio, by Marius R. Campbell, consists of five pages of text, a topographic sheet (scale 1 : 125,000), a sheet of areal geology, one of economic geology, another of structure sections, and, finally, a sheet giving a generalized columnar section of the district.

The territory mapped and described embraces an area of 950 square miles, the southern portion of which is in Virginia and the northern portion in West Virginia. It is located west of New (Kanawha) River at the place where the state line leaves East River Mountain, the last of the valley ridges toward the northwest, and follows the irregular crests of the ridges within the coal field. The southern portion of this territory is within the limits of the Appalachian valley, and its surface is marked by linear mountains and narrow valleys, which are the characteristic forms of this central division of the Appalachian province. The northern portion is within the Cumberland plateau region, and its surface is that of a tableland deeply dissected, so that it now

presents a confused mass of irregular ridges and hills, only the summits of which reach the original level of the plateau.

The geologic structure of this region varies as the topography varies. In the northern portion the rocks are nearly horizontal, their northwestward slope being rarely more than 200 feet per mile, whereas in the southern portion the rocks have been highly compressed in a horizontal direction, forming huge folds, which in many places have broken, allowing one portion of the fold to slip over the other. It is this tilted condition of the strata which gives rise to the regular topographic forms of the Appalachian valley. The attitude of the rocks is shown on the structure-section sheet by four sections which cross various portions of the territory.

The geologic history of this region is recorded in the rocks, which tell of prevailingly marine conditions from early Cambrian to late Carboniferous time. There were deposited during that time sediments to the extent of 17,000 or 18,000 feet in thickness, which have since been hardened into limestone, shale, and sandstone. Of this great mass the limestones form about 6700 feet; the shales 9500 feet; and the sandstones, about 1400 feet. On lithologic grounds these have been divided into twenty-three separate and distinct formations, which are shown on the general geologic map by various colors and patterns.

There is little variety in the mineral resources of this region. Coal, iron ore, and marble constitute about all of the mineral wealth of the territory. A limited area of coarse gray marble occurs along the northern front of Big Walker Mountain, but no development has been undertaken.

Iron ore occurs in two formations of the Upper Silurian rocks. It is of good quality, and probably in sufficient quantity to be of commercial importance, but its inaccessibility has prevented development.

Coal is by far the most important mineral resource of this region. The territory represented by this sheet embraces almost the entire Flat Top or Pocahontas coal field at present developed. All operations are confined to the great No. III or Pocahontas seam of coal, which is semi-bituminous and ranges in thickness from four to ten feet. It is exposed along the valley of Bluestone River from Pocahontas to the edge of the territory; along Tug Fork; in the valley of Elkhorn Creek from Coaldale to Kimball, near the edge of the area; and at several

places on the head streams of Guyandotte River. Mining is restricted to the Bluestone region and the valley of Elkhorn Creek. In these two areas there are at present in operation thirty-seven distinct mines, which in 1894 produced 3,096,867 long tons of coal.

Geologic Atlas of the United States. Folio 25, Loudon, Tennessee, 1896.

The Loudon folio represents that portion of the Appalachian province which is situated beween the parallels 35° 30′ and 36° and the meridians 84° and 84° 30′. This area contains 968 square miles, divided among Blount, Monroe, Loudon, Knox, Roane and Morgan counties, Tennessee. The folio consists of a topographic map, a geologic map, structure sections, stratigraphic sections, a map of the economic resources, and descriptive text. The author is Arthur Keith.

The text begins with a general description of the Appalachian province, and points out the relations of this area to the general region, with regard to its surface features. The local features of the drainage by the Tennesse River and its tributaries, Emory, Clinch, Tellico, and Little Tennessee, follow next in description. The various forms of surface, such as the great valley of Tennessee and the portions of the mountain district and the Cumberland plateau by which it is bounded, are pointed out, and the relation between these forms and the underlying rocks is made clear.

Under the heading "Stratigraphy," the geologic history of the Appalachian province is presented in outline, and the local rock groups are fully described in regard to composition, thickness, location, varieties, and mode of deposition. The formations, thirty-three in number, range in age from Cambrian, to Carboniferous; being, for the greater part, Cambrian and Silurian. The mountain district is chiefly underlain by the Ocoee series, whose age is doubtful. Rocks of Carboniferous and Devonian age occupy two small belts on either side of the great valley, and Silurian and Cambrian strata are repeated in narrow belts along it. Limestones, shales, and interbedded sandstones make up the Silurian and Cambrian strata; sandstones and shales with coal seams and a limestone near the base constitute the Carboniferous; and the Ocoee rocks are conglomerates, sandstone, slate, and limestone.

The details of the strata are graphically represented in the colum-

nar section. The different manners in which the formations decay is discussed, and the dependence of the residual soils and surface forms on the nature of the underlying rock is brought out. Great lithologic changes occur in the formations of this region, and the Knox dolomite is the only one which is uniform throughout. The direction of change was exactly reversed between Cambrian and Silurian times.

In the discussion of "Structure," after a general statement of the broader features of the province, two processes by which the strata of this quadrangle were deformed are noted. Of these the extreme Appalachian folding accompanied by faulting and metamorphism is by far the more prominent and is about equally developed throughout the quadrangle. Faults, especially, are most strikingly exhibited here. Deformation by vertical uplift is also exhibited, but it is only noticeable in comparison with broad surrounding areas. In this quadrangle the great valley is at its narrowest, on account of the extreme shortening in deformation. The structure sections illustrate the sharp folds and frequent faults into which the strata were forced. Economic products of this region are coal, variegated marble, red hematite, building stone, lime, clays, slate and timber. The outcrops of the formations containing these are indicated on the economic sheet, together with the locations of the mines and quarries. The iron ore and slate are at present of minor importance. The coal district is a part of the great coal basin of Tennessee, and the marble belts are a part of the principal productive region for that stone. Various conditions affecting the value of these deposits are pointed out, and the associations and availability of the building materials and timbers are discussed.

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The Morristown folio by Arthur Keith, deals with that portion of the Appalachian province which is situated between the parallels 36° and 36° 30′ and the meridians 83° and 83° 30′. This area contains 963 square miles, divided among the counties of Green, Cocke, Jefferson, Hamblen, Grainger, Claiborne, Hancock, and Hawkins, all in Tennessee. Included in the folio are topographic, economic, and geologic maps, structure and stratigraphic sections, and five pages of descriptive text.

After a description of the broader features of the Appalachian province, the local geography is analyzed. The various types of surface features are pointed out, and their relations to the underlying rocks are shown. Local phenomena such as elevations and the details of the drainage which is effected by the Nolichucky, French, Broad, Holston, and Clinch rivers, tributaries of the Tennessee, are detailed.

Under the heading "Stratigraphy" the geologic history of the Appalachians is presented in outline. This is followed by a detailed account of the local rock groups, in regard to their location, composition, thickness, variations, and mode of deposition. The soils and forms of surface produced by each formation are discussed with the formations. Twenty formations ranging from Cambrian to Carboniferous, are distinguished in this quadrangle; the greater portion being Cambrian and Silurian. The rocks of Carboniferous and Devonian age are found only in two narrow belts in the ridge district, and are represented by only four formations. Over the rest of the area Cambrian and Silurian strata are about equally represented. A great variety of limestones, shales, and sandstones compose the Cambrian and Silurian rocks. Shales and sandstones make up the Devonian, while only the limestone appears in the Carboniferous. Great changes take place in the Silurian strata; limestones on the northwest being represented by shales and sandstones at the southeast. The general character of the formations is graphically represented in the columnar sections, one being drawn for each of the two chief geologic districts.

In the discussion of structure, after a general statement of the broader features of Appalachian structure, the two types of deformation shown in this region are described, and illustrations are pointed out in the structure sections. In the ridge district the most prominent feature is the faulting, which has cut the strata into long narrow blocks and produced the characteristic ridge topography. Southeast of Holston River the rocks were deformed by close folds. Deformation by vertical uplift is also present, but it can only be observed in comparison with other and larger areas. In the structure sections, most of the details of the different structures are shown.

Economic products of this region are marble, building stone, lead, zinc, cement, clays, and timber. The outcrops of the formations containing these are represented on the economic sheet as far as possible, together with the locations of mines and quarries. The principle

industries are the production of zinc and marble; the timbers and water powers are also of general importance. The various conditions which affect the development of these resources are discussed.

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